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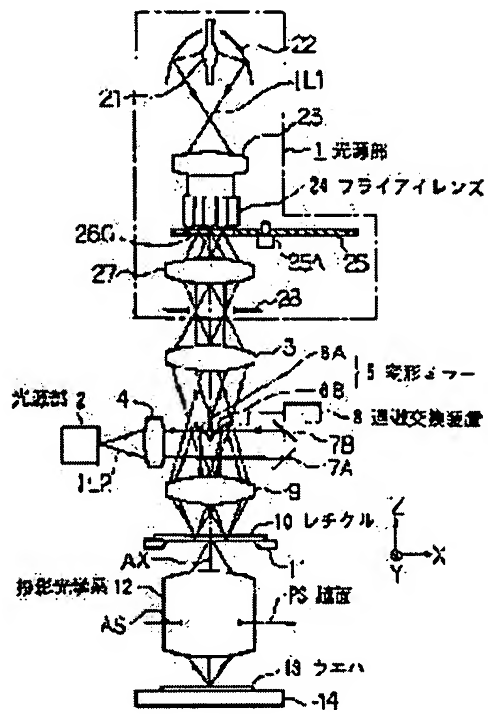
(54) PROJECTION ALIGNER

(57)Abstract:



PROBLEM TO BE SOLVED: To provide a projection aligner which can suppress fluctuations in high order spherical aberration when zonal illumination or modified illumination is carried out.

SOLUTION: Apart from a light source unit 1 for light exposure, another light source unit 2 is provided for emitting illumination light IL2 having such wavelengths that will not be sensitive to photoresist on a wafer 13. Provided on an optical path of illumination light IL1 is a modified mirror 5 of mirrors 6A and 6B having reflecting surfaces tilted toward a reticle 10. The illumination light IL1 for light exposure from the light source unit 1 is passed through a zonal region around the modified mirror 5; while the illumination light IL2 for non-exposure is reflected by the reflecting surfaces of the modified mirror 5 to be directed toward the reticle 10 and a projection optical system 12. With the illumination light IL1 and IL2, a lens in the vicinity of a pupil surface of the projection optical system 12 can be illuminated with a uniform illumination distribution.

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CLAIMS

[Claim(s)]
[Claim 1] The projection optics which projects the image of the pattern on a mask on a sensitization substrate under the illumination light for exposure, In the projection aligner which has the illumination-light study system which illuminates said mask using the illumination light for said exposure from the light source distributed over the field which carried out eccentricity from an optical axis on the pupil surface of said projection optics, and a field [****] The projection aligner characterized by establishing the auxiliary illumination system which irradiates the illumination light of a nonphotosensitivity wavelength region to the field through which the illumination light for said exposure does not pass on the pupil surface of said projection optics to said sensitization substrate.
[Claim 2] It is the projection aligner characterized by being a projection aligner according to claim 1, and said illumination-light study system illuminating said mask by the illumination light for said exposure from the zona-orbicularis-like light source or two or more light sources in the location which carried out eccentricity to the optical axis.
[Claim 3] It is the projection aligner which has an optical integrator to be a projection aligner claim 1 or given in two, and for said illumination-light study system equalize the illuminance distribution of the illumination light for said exposure, and is characterized by preparing the fill-in flash induction material which leads the illumination light from said auxiliary illumination system to said mask between this optical integrator and said mask.
[Claim 4] In the projection aligner using the image formation flux of light which passes through the field which carried out eccentricity from the optical axis on the pupil surface of said projection optics in case the image of the pattern on a mask is projected on a sensitization substrate through projection optics under the illumination light for exposure The synthetic illumination-light study system which leads the nonphotosensitivity illumination light to the pupil surface of said projection optics to the illumination light and said sensitization substrate for said exposure, The projection aligner characterized by having the optical member which has the wavelength selection nature which passes only the nonphotosensitivity illumination light to said sensitization substrate side to said sensitization substrate in fields other than the field which it has been arranged on the pupil surface of said projection optics, and carried out eccentricity from said optical axis.

[Translation done.]

* NOTICES *

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention is applied to the projection aligner which especially performs zona-orbicularis lighting etc. or uses the pupil filter of a main protection-from-light mold about the projection aligner used in order to expose the image of the pattern on a mask on a sensitization substrate at the photolithography process for manufacturing a semiconductor device, a liquid crystal display component, image sensors (CCD etc.), or the thin film magnetic head, and is suitable.
[0002]
[Description of the Prior Art] In case the former, for example, a semiconductor device, is manufactured, projection aligners, such as a stepper who imprints on the wafers (or glass plate etc.) with which the image of the patterns (or photo mask etc.) of the reticle as a mask was applied to the photoresist as a sensitization substrate through projection optics, are used. In these projection aligners, in order to expose the pattern of a high degree of integration as much as possible to a wafer, while using the illumination light of short wavelength as much as possible as an exposure light, efforts of enlarging numerical aperture (NA) of projection optics and raising the resolution of the pattern imprinted have been made.
[0003] However, the illumination which secures the depth of focus more than a certain extent, and obtains high resolution of making exposure light inclining to a reticle as an approach, and illuminating is developed, without being not much dependent on numerical aperture, since the depth of focus becomes narrow too much if numerical aperture of projection optics is only enlarged. This illumination has the so-called deformation lighting made into the small light source of plurality (for example, four pieces) which carried out eccentricity of the configuration of the zona-orbicularis lighting which makes the configuration of the secondary light source of an illumination-light study system the shape of zona orbicularis, and its secondary light source from the optical axis. According to such illumination, the resolution of projection optics improves also with the same exposure wavelength and the numerical aperture of the same projection optics. Moreover, pupil filters, such as the shape of zona orbicularis, are arranged to the pupil surface of projection optics, and the approach of raising resolution by the so-called "super resolution" is also developed.
[0004]
[Problem(s) to be Solved by the Invention] According to the lighting which illuminates the flux of light which does not use zona-orbicularis lighting etc. but carries out incidence of the reticle perpendicularly to a reticle in the above conventional technique with the exposure light uniformly distributed as a core As for the lens near the pupil surface of projection optics, a core and a periphery are illuminated by about 1 appearance in order to form the image of the pattern on a wafer according to the 3 flux of lights of the zero-order diffracted light which mainly passed the pattern of a reticle, the +primary diffracted light, and the -primary diffracted light. Moreover, also when not arranging the pupil filter of the shape of zona orbicularis which covers a core to the pupil surface of projection optics under the usual illumination, the lens near the pupil surface of projection optics is illuminated uniformly. If it is in such a lighting condition, in order that the core of a lens may mainly carry out a temperature rise, the heat

deformation and refractive-index change it is changeless less than in the secondary function about a location mainly take place, and only migration of the gauss (Gauss) image surface arises as main aberration fluctuation near an optical axis. Therefore, there were few possibilities that high order spherical-aberration fluctuation of projection optics might occur.
[0005] However, when it illuminates by zona-orbicularis lighting or deformation illumination, in order [of the illumination light for exposure which passed the pattern of a reticle] to mainly form the image of the pattern on a wafer by the zero-order diffracted light and the primary diffracted light, when there are many patterns near the limit-line width of face of the resolution of projection optics, the amount of the beam of light which penetrates near the optical axis of projection optics decreases extremely compared with a periphery. Moreover, even when the pupil filter which shaded near the optical axis to the pupil surface of projection optics has been arranged, the amount of the beam of light which penetrates near the optical axis of the lens arranged at the side near a wafer becomes less than a pupil surface extremely compared with a periphery.
[0006] Thus, if distribution of the exposure energy to the lens of projection optics becomes an ununiformity, the phenomenon in which the periphery of a lens mainly absorbs and carries out the temperature rise of the heat, and a core does not carry out a temperature rise will happen. Since the refractive index of a lens is changed partially or a lens carries out heat deformation in proportion to such a temperature rise, the refractive-index distribution equivalent to the aspheric surface and it higher order than the 2nd order is newly formed. Therefore, in the part near the optical axis of projection optics, there was un-arranging [that high order spherical-aberration fluctuation newly arose not only in migration of the gauss image surface by the exposure of exposure light].
[0007] In case this invention is exposed in view of this point using the pupil filter which shades near an optical axis, using zona-orbicularis lighting, deformation lighting, etc., it aims at offering the projection aligner with which high order spherical-aberration fluctuation of projection optics is suppressed, and high resolution is obtained.
[0008]
[Means for Solving the Problem] The 1st projection aligner by this invention For example, the projection optics which projects the image of the pattern on a mask (10) on a sensitization substrate (13) under the illumination light for exposure (IL1) as shown in drawing 1 (12), The pupil surface of the projection optics, Namely, the illumination-light study system which illuminates the mask (10) using the illumination light (IL1) for the exposure from the light source (the secondary light source is included) distributed over the field which carried out eccentricity from an optical axis (AX) on the optical Fourier transform side (PS) over the pattern side of a mask (10), and a field [****] (1, 3, 9), In the projection aligner which ****, the auxiliary illumination system (2) which irradiates the illumination light (IL2) of a nonphotosensitivity wavelength region to the field through which the illumination light for the exposure (IL1) does not pass on the pupil surface (PS) of the projection optics (12) is established to the sensitization substrate (13).
[0009] According to the 1st projection aligner of this this invention, it means using zona-orbicularis illumination and deformation illumination as using the illumination light for the exposure from the light source (IL1) distributed over the field which carried out eccentricity from the optical axis (AX) on the pupil surface (PS) of projection optics (12), and the field [****]. In this case, the lens near the pupil surface of projection optics (12) is illuminated by the illumination light for exposure in the field which mainly carried out eccentricity from the optical axis (IL1), for example, high resolution is obtained to a predetermined periodic pattern. Moreover, since the field through which the illumination light for exposure (IL1) does not pass on the pupil surface (PS) of projection optics (12) according to an auxiliary illumination system, i.e., the field near the optical axis, is illuminated by the nonphotosensitivity illumination light (IL2) to a sensitization substrate, the illumination distribution over the lens near the pupil surface (PS) of projection optics (12) becomes homogeneity, and the high order fluctuation component in heat deformation of a lens or change of a refractive index decreases. for this reason -- being alike -- the nonphotosensitivity illumination light (IL2) needs to be absorbed by the lens of projection optics (12), or the coating film of this lens with an absorption coefficient comparable as the

illumination light for exposure (IL1). Since spherical-aberration fluctuation of a lens is proportional to heat deformation of a lens or change of a refractive index, high order spherical-aberration fluctuation of projection optics (12) is suppressed. However, since the illumination light (IL2) from an auxiliary illumination system (2) is nonphotosensitivity, there is no effect in the image imprinted on a sensitization substrate (13).
[0010] In this case, as for that illumination-light study system, it is desirable to illuminate that mask (10) by the illumination light for that exposure from the zona-orbicularis-like light source or two or more light sources in the location which carried out eccentricity to the optical axis (IL1). This means the illumination by the so-called zona-orbicularis lighting and deformation lighting, and, thereby, high resolution is obtained. Moreover, as for that illumination-light study system, it is desirable to have an optical integrator (24) for equalizing the illuminance distribution of the illumination light for that exposure (IL1), and to prepare the fill-in flash induction material (4, 6A-6D, 7A, 7B) which leads the illumination light (IL2) from that auxiliary illumination system (2) to that mask (10) between this optical integrator and its mask (10). Thereby, the illumination light (IL1) and illumination light (IL2) for exposure are easily compoundable.
[0011] Moreover, as the 2nd projection aligner by this invention is shown in drawing 6 In case the image of the pattern on a mask (10) is projected on a sensitization substrate (13) through projection optics (12) under the illumination light for exposure (IL1B) In the projection aligner using the image formation flux of light which passes through the field which carried out eccentricity from the optical axis (AX) on the pupil surface (PS) of the projection optics (12) The synthetic illumination-light study system which leads the nonphotosensitivity illumination light (IL2B) to the pupil surface (PS) of the projection optics to the illumination light (IL1B) and its sensitization substrate (13) for the exposure (1B, 42, 2B, 4B, 7A, 8A), It is arranged on the pupil surface (PS) of the projection optics (12), and has the optical member (5B) which has the wavelength selection nature which passes only the nonphotosensitivity illumination light (IL2B) to the sensitization substrate side to the sensitization substrate (13) in fields other than the field which carried out eccentricity from the optical axis.
[0012] In order to use the image formation flux of light which passes through the field which carried out eccentricity from the optical axis (AX) on the pupil surface (PS) of projection optics (12) according to the 2nd projection aligner of this this invention, it becomes using the pupil filter of a main protection-from-light mold substantially, and equivalence, and high resolution is obtained. In this case, by the optical member (5B), the illumination light for exposure (IL1B) passes only through fields, such as the shape of zona orbicularis, and the nonphotosensitivity illumination light (IL2B) passes through fields other than the field which carried out eccentricity from that optical axis to a sensitization substrate (13). Therefore, since the lens near the pupil surface (PS) of projection optics (12) is irradiated by two illumination light (IL1B, IL2B) by uniform illumination distribution, the high order fluctuation component in heat deformation of a lens or change of a refractive index decreases, and high order spherical-aberration fluctuation also decreases. And the nonphotosensitivity illumination light (IL2B) does not affect the projection image on a sensitization substrate (13).
[0013]
[Embodiment of the Invention] Hereafter, with reference to drawing 1 - drawing 3 , it explains per 1st example of the gestalt of operation of the projection aligner of this invention. This example applies this invention to the projection aligner of the stepper mold which projects the pattern on a reticle on each shot field on a wafer through projection optics.
[0014] As drawing 1 shows the outline configuration of the projection aligner of this example and it is shown in this drawing 1 , the three light source sections (in drawing 1 , the two light source sections 1 and 2 have appeared) are prepared in the projection aligner of this example. At the time of exposure, from the 1st light source section 1, the illumination light IL 1 of the photosensitive wavelength lambda 1 is injected by the photoresist on a wafer 13, and the illumination light IL 2 of the nonphotosensitivity wavelength lambda 2 is injected by the photoresist on a wafer 13 from the 2nd light source section 2 and the 3rd non-illustrated light source section. After the illumination light injected from the light source 21 which consists of a mercury lamp of the light source section 1 condenses to the 2nd focus in the ellipse

mirror 22, it turns into emission light and carries out incidence to a non-illustrated interference filter etc., and the illumination light IL 1 of i line (wavelength of 365nm) is extracted by the interference filter. Next, the illumination light IL 1 serves as the parallel flux of light with the input lens 23, and carries out incidence to the fly eye lens 24 as an optical integrator. The secondary light source is formed in each injection side of each lens element of the fly eye lens 24, and the surface light source is made by these secondary light sources. In the injection side of the fly eye lens 24, two or more aperture diaphragms 26A-26C (refer to drawing 2 (a)) in which the switch for adjusting the magnitude of the surface light source is free are arranged. These aperture diaphragms 26A-26C are fixed to the turret-like disk 25, and a desired aperture diaphragm can be set as the injection side of the fly eye lens 24 by rotating a disk 25 by driving gear 25A.

[0015] Drawing 2 (a) shows the top view for explaining the concrete configuration of the aperture diaphragm on the disk 25 of drawing 1 , and three aperture diaphragms 26A-26C are being fixed around the turret-like disk 25 by the equiangular distance in this drawing 2 (a). 1st aperture-diaphragm 26A has circular opening used when performing the usual lighting, and 2nd aperture-diaphragm 26B has small circular opening used when illuminating by the small coherence factor (sigma value). 3rd aperture-diaphragm 26C has big circular opening, and in this example, when performing zona-orbicularis lighting or deformation lighting, it sets the 3rd aperture-diaphragm 26C as the injection side of the fly eye lens 24. That is, at the time of zona-orbicularis lighting, aperture-diaphragm 26D of the shape of zona orbicularis shown in drawing 2 (b) is usually used, and aperture-diaphragm 26E which has four small openings arranged considering the optical axis shown in drawing 2 (c) as a core is used at the time of deformation lighting. However, in this example, aperture-diaphragm 26D etc. is substantially made to serve a double purpose by the below-mentioned deformation mirror 5 grade. In drawing 1 , 3rd aperture-diaphragm 26C is arranged on the optical path of the illumination light IL 1.

[0016] The illumination light IL 1 which passed aperture-diaphragm 26C penetrates the 1st relay lens 27, and the lighting range is prescribed by the field diaphragm (reticle blind) 28. The illumination light IL 1 as which the lighting range was specified passes through the perimeter of the deformation mirror 5 which consists of four mirrors 6A-6D (drawing 1 shows two of the mirrors 6A and 6B of it) which were injected from the light source section 1 and have been arranged in the shape of [of concave] 4 pyramids centering on the optical axis AX of an illumination-light study system through the 2nd relay lens 3 at the 2nd relay lens 3 side. The reflector of four mirrors of the deformation mirror 5 turns to an outside, and inclines about 45 degrees to the optical axis AX of an illumination-light study system. Furthermore, the top face of the deformation mirror 5 is arranged in the location [**** / the arrangement side of aperture-diaphragm 26C]. Incidence of the illumination light IL 1 which passed through the perimeter of the deformation mirror 5 is carried out to a reticle 10 through a condensing lens 9.

[0017] Drawing 3 (a) shows drawing which saw the deformation mirror 5 of drawing 1 from the reticle 10 side, in this drawing 3 (a), it is an equal configuration mutually, and it is close and Mirrors 6A-6D are arranged so that four[which make the optical axis AX of an illumination-light study system top-most vertices] -sided pyramids may be formed. Moreover, the appearance 17 of the base of Mirrors 6A-6D forms one periphery centering on an optical axis AX as a whole. And it is constituted so that the illumination light IL 1 may pass through the field 15 of the shape of zona orbicularis between the appearance 17 and periphery 16 of the image of opening of aperture-diaphragm 26C of drawing 1 . That is, the deformation mirror 5 of this example is making the zona-orbicularis-like aperture diaphragm serve a double purpose.

[0018] Return and the deformation mirror 5 are constituted by drawing 1 so that it can exchange for another deformation mirror, while being able to evacuate with the evacuation swap device 8 at the outside of the optical path of the illumination light IL 1. Next, the 2nd light source section 2 is constituted including the lens system which emits the light source for un-exposing, and the flux of light from the light source on a predetermined flare square. And the nonphotosensitivity illumination light IL 2 is made the parallel flux of light by the relay lens 4, and carries out incidence to the photoresist injected from the light source section 2 arranged at the upper left section of a reticle 10 at mirror 6A in the deformation mirror 5 from the direction where the optical axis AX of an illumination-light study

system and a part cross at right angles. A part of illumination light IL 2 is caudad turned by mirror 6A, and it is reflected. The illumination light IL 2 which passed the lower part of mirror 6A carries out incidence of the flux of light which was reflected by Mirrors 7A and 7B, carried out incidence to mirror 6B in the deformation mirror 5, and was reflected by mirror 6B to a condensing lens 9 with the flux of light reflected by mirror 6A. Although not illustrated The optical system which consists of the light source section 2, a relay lens 4, and mirrors 7A and 7B, and the same optical system are arranged also in the direction perpendicular to the space of drawing 1 . The nonphotosensitivity illumination light (also let this be the illumination light IL 2) is caudad reflected in a photoresist by the mirrors 6C and 6D (refer to drawing 3) in the deformation mirror 5 from the 3rd light source section arranged in the direction perpendicular to the space of this drawing 1 . Therefore, the illumination light IL 2 is reflected in the circular field inside the zona-orbicularis-like field 15 through which the illumination light IL 1 passes in drawing 3 (a).

[0019] In drawing 1 , both the illumination light IL 2 reflected by the illumination light IL 1 which passed through the perimeter of the deformation mirror 5, and the deformation mirror 5 is irradiated on a reticle 10 with a condensing lens 9. The illumination light IL1 and IL2 irradiated on the reticle 10 passes the pattern space on a reticle, and is irradiated on a wafer 13 through projection optics 12. Under the illumination light IL 1 for exposure, about projection optics 12, the pattern side of a reticle 10 and the front face of a wafer 13 are conjugation, and since the illumination light IL 2 is nonphotosensitivity at the photoresist on a wafer 13, only the pattern image on the reticle 10 illuminated by the illumination light IL 1 for the exposure exposes the photoresist on a wafer 13. In this case, the optical Fourier transform sides over the pupil surface PS within projection optics 12, i.e., the pattern side of a reticle 10, are ****** of aperture-diaphragm 26C as a result the top face of the deformation mirror 5, and conjugation, and aperture-diaphragm AS is arranged at the pupil surface PS.

[0020] Although the wavelength lambda 1 of the illumination light IL 1 and the wavelength lambda 2 of lighting IL 2 change with classes of ** material which forms the class of photoresist, and the lens of projection optics 12 etc., in the usual case, wavelength lambda 1 chooses less than 530nm, and wavelength lambda 2 chooses the wavelength of 530nm or more. As illumination light IL 1 for exposure, although i line of a mercury lamp is used in this example, the bright line, ArF excimer laser light (wavelength of 193.2nm) and KrF excimer laser light (wavelength of 248.5nm) or copper steamy laser of a mercury lamp, such as g line (wavelength of 436nm), the higher harmonic of an YAG laser, etc. can be used in addition to it. Moreover, as illumination light IL 2, it is the wavelength which does not expose a photoresist, and the thing near the illumination light IL 1 as a whole has the desirable amount of light absorption per unit area in the ** material or coating film of a lens. From the semantics, as illumination light IL 2, when the rate of light absorption is small, the optical reinforcement of the light source is strong, and when the optical reinforcement of the light source is small on the other hand, the biggest possible thing of the rate of light absorption to the ** material or coating film of a lens of projection optics 12 is desirable. As an example of the illumination light IL 2, the laser beam (wavelength of 633nm) from helium-Ne laser etc. is mentioned, for example.

[0021] In addition, when predetermined glass with the good permeability from a quartz or an ultraviolet area to a near-infrared region is used as ** material for the lenses of projection optics, since these ** material has a remarkable rate of light absorption from long wave length about 2 micrometers or more, it may use HF chemical laser light (wavelength of 2.4-3.4 micrometers) using the chemical reaction of hydrogen fluoride (HF) gas etc. as illumination light IL 2. Moreover, since optical glass other than a quartz contains the impurity, its illumination light which even the wavelength of 530nm or more has some which have a rate of light absorption near [cm] in 1% /, and has such a rate of light absorption near [cm] in 1% /is also effective enough. As an example of such illumination light, C line (wavelength of 656.3nm) from the hydrogen (H2) discharge tube, d line (wavelength of 587.6nm) from the helium (helium) discharge tube, etc. are mentioned. In drawing 1 , the optical axis AX of an illumination-light study system has agreed with the optical axis of projection optics 12, below, takes the Z-axis in parallel with an optical axis AX, and takes and explains a Y-axis to the space of drawing 1 on a two-dimensional flat surface perpendicular to the Z-axis at right angles to the space of the X-axis and drawing 1 in

parallel.
[0022] The reticle 10 is laid on the reticle stage 11 which can be moved slightly to the direction of X, the direction of Y, and a hand of cut. The location of a reticle stage 10 is measured by the precision with the external laser interferometer (un-illustrating), and the location of a reticle stage 11 is controlled based on the measured value of the laser interferometer. On the other hand, a wafer 13 is laid on the wafer stage 14 which positions a wafer to the direction of X, the direction of Y, and a Z direction through a non-illustrated wafer holder, the location of the wafer stage 14 is measured by the precision with the external laser interferometer, and the location of the wafer stage 14 is controlled based on the measurement value. The actuation which moves by the wafer stage 14 at the core of each shot field of a wafer 13 focusing on exposure of projection optics 12, and exposure actuation are repeated by the step-and-repeat method, and the image of the pattern on a reticle 10 is imprinted by each shot field on a wafer 13.
[0023] Next, actuation of the projection aligner of this example is explained. In this example, since zona-orbicularis lighting is substantially performed by the illumination light IL 1 for exposure combining aperture-diaphragm 26C which has big opening, and the deformation mirror 5 as first shown in drawing 1 , high resolution is obtained to a periodic predetermined pattern. Moreover, as shown in drawing 3 (a), the nonphotosensitivity illumination light IL 2 passes through the field inside a field 15 on the pupil surface PS of projection optics 12, and a field [**** / almost] to the photoresist which the photosensitive illumination light IL 1 passed through the zona-orbicularis-like field 15 to the photoresist, and was reflected according to the reflector of the deformation mirror 5. If incidence of the illumination light IL1 and IL2 is carried out to projection optics 12 through the reticle 10 of drawing 1 in the state of such lighting, illumination light IL1 and IL2 will pass through the inside of the circular field centering on an optical axis AX as a whole on the pupil surface PS of projection optics 12. Therefore, the lens of the projection optics 12 of a near [the pupil surface PS] absorbs and carries out the temperature rise not only of a periphery but the core for heat energy. Therefore, with the lens near pupil surface PS, the rate of the secondary fluctuation component, heat deformation and refractive-index change, becomes large to a high order fluctuation component. Since spherical-aberration fluctuation of projection optics 12 is proportional to heat deformation of the lens near pupil surface PS, or change of a refractive index mostly, the secondary component of spherical-aberration fluctuation increases and high order spherical-aberration fluctuation of projection optics 12 is suppressed.
[0024] In addition, although the deformation mirror 5 for zona-orbicularis lighting was used in drawing 1 , 4 pyramid-like deformation mirror 5A (refer to drawing 3 (b)) which makes aperture-diaphragm 26E for deformation lighting shown in drawing 2 (c) serve a double purpose is also prepared in this example. That is, when performing deformation lighting, deformation mirror 5A is set up on the optical path of the illumination light IL 1 instead of the deformation mirror 5 through the evacuation swap device 8 of drawing 1 .
[0025] Drawing 3 (b) shows drawing which looked at deformation mirror 5A for deformation lighting from the reticle 10 side of drawing 1 , in this drawing 3 (b), it is an equal flabellate form mutually, and it is close and four mirrors 19A-19D which constitute deformation mirror 5A are arranged so that four [which turned the convex to the reticle 10 which makes an optical axis AX top-most vertices] -sided pyramids may be formed. Moreover, as for Mirrors 19A-19D, the field by the side of a reticle 10 is one centering on optical axis AX periphery [appearance / which was seen from the reticle 10 of Mirrors 19A-19D by being a reflector]-as a whole 16A. This periphery 16A is almost equal to the periphery 16 of the circular field through which the illumination light IL 1 of drawing 3 (a) passes. Moreover, by the equiangular distance, it sees from a reticle 10 side inside periphery 16A of the appearance of each mirrors 19A-19D, and the circular transparency sections 18A-18D are formed in it, and it is constituted so that the illumination light IL 1 for exposure of drawing 1 may penetrate these transparency sections 18A-18D. This deformation mirror 5A is making aperture-diaphragm 26E for the deformation lighting of drawing 2 (c) serve a double purpose.
[0026] That is, through the evacuation swap device 8 of drawing 1 , when performing deformation lighting by this example, the top-most vertices are turned to a reticle 10 side, and deformation mirror 5A

is arranged instead of the deformation mirror 5 of drawing 1 , so that the top-most vertices of a pyramid may be in agreement with an optical axis AX. The illumination light IL 1 penetrates the four transparency sections 18A-18D, and is irradiated on the reticle 10 of drawing 1 by this. On the other hand, it is reflected in the field except the transparency sections 18A-18D within periphery 16A of drawing 3 (b), and the illumination light IL 2 for un-exposing is irradiated on a reticle 10. Since the top faces of deformation mirror 5A are the pupil surface PS of projection optics 12, and conjugation, on the pupil surface PS of projection optics 12, the circular field centering on an optical axis AX is illuminated by illumination light IL1 and IL2. Therefore, while high resolution is obtained by deformation illumination, high order spherical-aberration fluctuation is suppressed. And the illumination light IL 2 for un-exposing does not have a bad influence on an image formation property. Moreover, what is necessary is to evacuate the deformation mirrors 5 and 5A from the optical path of the illumination light IL 1 through the evacuation swap device 8, and just to set up the aperture diaphragms 26A and 26B of drawing 2 (a) as an aperture diaphragm in drawing 1 , when using the usual illumination.
[0027] In addition, the photosensitive illumination light IL 1 is reflected in a photoresist in the reflector of the deformation mirrors 5 and 5A of drawing 3 (a) or drawing 3 (b), and you may make it a configuration which shades a part of nonphotosensitivity illumination light IL 2 to a photoresist. What is necessary is to prepare the circular transparency section, for example instead of the deformation mirror 5 of drawing 3 (a), so that the illumination light IL 2 may penetrate in the center section, and just to use the deformation mirror which has the zona-orbicularis-like reflector in which the illumination light IL 1 which carries out incidence from the direction which intersects perpendicularly around the transparency section to the illumination light IL 2 is reflected, while replacing the light source sections 1 and 2 and related arrangement of optical system in drawing 1 when making it such a configuration.
[0028] Next, the modification of the 1st example of the gestalt of operation of this invention is explained with reference to drawing 4 . This modification is again divided into two illumination light by the aperture diaphragm which has the wavelength selection nature which compounded beforehand the illumination light for exposure, and the illumination light of nonphotosensitivity [photoresist], and prepared the synthetic light before the reticle 10, and it is constituted so that a reticle 10 may be illuminated. In drawing 4 , the same sign is given to the part corresponding to drawing 1 , and the detail explanation is omitted.
[0029] Drawing 4 showed the outline configuration of the projection aligner of this modification, and arranges light source section 1A which injects photosensitive illumination-light IL1A to a photoresist like the light source section 1 of drawing 1 , and light source section 2A which injects nonphotosensitivity illumination-light IL2A to a photoresist like the light source section 2 of drawing 1 in the form where a location is mutually replaced with, in this drawing 4 . And the polarization beam splitter 31 is arranged in the location where those illumination-light IL1A and illumination-light IL2A cross. Illumination-light IL1A and IL2A of this modification presuppose that it is the linearly polarized light of P polarization, respectively. Illumination-light IL2A of P polarization of wavelength lambda 2 injected from the field diaphragm of light source section 2A is made the parallel flux of light by relay lens 4A, penetrates a polarization beam splitter 31, and is changed into the circular polarization of light by the quarter-wave length plate 34. On the other hand, it is injected from the field diaphragm of light source section 1A, and a polarization beam splitter 31 is penetrated from the direction which intersects perpendicularly with the optical path of illumination-light IL2A, it is reflected by the mirror 33 through the quarter-wave length plate 32, and incidence of the illumination-light IL1A of P polarization made the parallel flux of light by relay lens 3A is again carried out to the quarter-wave length plate 32, and it is changed into S polarization. It is reflected by the polarization beam splitter 31, and incidence of the illumination-light IL1A changed into S polarization is carried out to the quarter-wave length plate 34, and it is changed into the circular polarization of light. Incidence of illumination-light IL1A changed into the circular polarization of light by the quarter-wave length plate 34 and the IL2A is carried out to the aperture diaphragm 37 which has wavelength selection nature through relay lenses 35 and 36.
[0030] Drawing 5 (a) shows the top view of an aperture diaphragm 37, and the aperture diaphragm 37 consists of a light filter 39 of the shape of zona orbicularis which penetrates illumination-light IL1A of

wavelength lambda 1, and hardly penetrates illumination-light IL2A of wavelength lambda 2, and a circular light filter 38 which penetrates illumination-light IL2A of wavelength lambda 2, and hardly penetrates the illumination light IL 1 of wavelength lambda 1 in this drawing 5 (a). Moreover, the aperture diaphragm 37 is arranged on the pupil surface PS of projection optics 12, and the field [****] so that a core may agree in an optical axis AX. And illumination-light IL1A from light source section 1A is irradiated by the field containing the zona-orbicularis-like light filter 39, and illumination-light IL2A from light source section 2A is irradiated by the field containing the circular light filter 38.

[0031] After two illumination-light IL1A compounded by the polarization beam splitter 31 and IL2A pass an aperture diaphragm 37, they are irradiated on a reticle 10 through a condensing lens 9. The pattern image of a reticle 10 is projected on a wafer 13 through projection optics 12. On the pupil surface PS of projection optics 12, the same illumination-light IL1A as the 1st example and IL2A pass through an almost circular field. The optical path of the following illumination-light IL1A and IL2A is attached like the 1st example, and omits explanation.

[0032] While the same high order spherical-aberration reduction effectiveness as the 1st example is acquired, in order for the aperture diaphragm 37 which has wavelength selection nature to prescribe the passage field of illumination-light IL1A and IL2A according to this modification, the complicated configuration of using the deformation mirror 5 like the 1st example is unnecessary. Moreover, since light source section 2A of wavelength lambda 2 can be managed with one, the whole equipment can be constituted in a compact. Moreover, since the 2 flux of lights of the linearly polarized light compounded by the polarization beam splitter 31 are changed into the circular polarization of light by the quarter-wave length plate 34, in case image formation is carried out on a wafer 13, a good imprint is performed even if the direction of the pattern of a reticle 10 changes. In addition, as it replaces with a polarization beam splitter 31 and the two-dot chain line of drawing 4 shows, dichroic mirror 31A can also be used. This dichroic mirror 31A penetrates illumination-light IL2A, it has the wavelength selection nature which reflects illumination-light IL1A, and both illumination-light IL1A and IL2A are compounded by this without futility. In this case, the quarter-wave length plates 32 and 34 and a mirror 33 become unnecessary, and it becomes easy to constitute them. Moreover, the aperture diaphragm 37 of drawing 4 is constituted so that it can exchange for aperture-diaphragm 37A for deformation lighting with the evacuation swap device 8 of drawing 1 , and the same equipment.

[0033] In case drawing 5 (b) performs deformation lighting, it shows the top view of aperture-diaphragm 37A which has the wavelength selection nature used instead of the aperture diaphragm 37 of drawing 4 , and it sets it to this drawing 5 (b). Aperture-diaphragm 37A Four small circular light filters 40A-40D which penetrate illumination-light IL1A of wavelength lambda 1, and hardly penetrate illumination-light IL2A of wavelength lambda 2, And the appearance which penetrates illumination-light IL2A of wavelength lambda 2 in the field except these light filters 40A-40D, and hardly penetrates illumination-light IL1A of wavelength lambda 1 consists of circular light filters 41. A light filter 41 has an outer diameter almost equal to the outer diameter of the light filter 39 of drawing 5 (a), it has four small circular openings formed by the equiangular distance near [the] the periphery, and light filters 40A-40D are formed in these four openings, respectively. Illumination-light IL1A for exposure passes four light filters 40A-40D, and nonphotosensitivity illumination-light IL2A passes the light filter 41 around the light filters 40A-40D to a photoresist. While deformation lighting is performed by this, high order spherical-aberration fluctuation is controlled.

[0034] In addition, in drawing 5 (a) and drawing 5 (b), the effectiveness that what does not penetrate illumination-light IL2A from light source section 2A as much as possible reduces high order spherical-aberration fluctuation as the light filter 38 which illumination-light IL1A from light source section 1A penetrates, and 40A-40D is large, and desirable. Next, the 2nd example of the gestalt of operation of the projection aligner of this invention is explained with reference to drawing 6 . This example applies this invention, when using a zona-orbicularis-like pupil filter. In addition, in drawing 6 , the same sign is given to the part corresponding to drawing 1 , and the detail explanation is omitted.

[0035] Drawing 6 shows the outline configuration of the projection aligner of this example, and in this drawing 6 , since it is easy, it divides and explains projection optics 12 to up lens system 12A and lower

lens system 12B. In this example, deformation mirror 5B of the 4 same pyramid molds as the deformation mirror 5 of drawing 1 is arranged near the pupil surface PS between those up lens system 12A and lower lens system 12B. Illumination-light IL1B of the photosensitive wavelength lambda 1 is irradiated on a reticle 10 through a condensing lens 42 by the photoresist injected from the field diaphragm of the same light source section 1B as the light source section 1 of drawing 1 . the aperture diaphragm in light source section 1B is the same as that of aperture-diaphragm 26C of drawing 2 (a) -- big -- it is circular. The Fourier transform of the illumination-light IL1B which penetrated the reticle 10 is optically carried out by up lens system 12A, and it passes through the perimeter of deformation mirror 5B. Photosensitive illumination-light IL1B is shaded in the circular field centering on an optical axis AX by this deformation mirror 5B at a photoresist. That is, deformation mirror 5B is making the zona-orbicularis-like pupil filter serve a double purpose. After nonphotosensitivity illumination-light IL2B is made into the parallel flux of light by relay lens 4B, a part is reflected in the photoresist of wavelength lambda 2 injected on the other hand from the same light source section 2B as the light source section 2 of drawing 1 towards a wafer 13 side in the 1st reflector of deformation mirror 5B. In this case, illumination-light IL2B which passed the lower part of deformation mirror 5B like the 1st example of drawing 1 is reflected, and the mirrors 7A and 8A for making the 2nd reflector of deformation mirror 5B carry out incidence are arranged.

[0036] Furthermore, the light source section which supplies the illumination light of wavelength lambda 2 in the direction perpendicular to the space of drawing 6 to the 3rd and 4th reflectors of deformation mirror 5B also by this example is prepared. Illumination-light IL2B reflected by deformation mirror 5B is irradiated on a wafer 13 through lower lens system 12B. In this example, since the field near the optical-axis AX of illumination-light IL1B for exposure is shaded by deformation mirror 5B arranged at the pupil surface PS of projection optics 12, the same high resolution as the case where the pupil filter of a main zona-orbicularis-like protection-from-light mold is installed to a predetermined pattern is obtained. Moreover, since the ** material of lower lens system 12B is illuminated by two waves of illumination-light IL1B and IL2Bs by uniform illumination distribution, high order heat deformation and change of a refractive index are suppressed, and high order spherical-aberration fluctuation of projection optics 12 is suppressed.

[0037] In addition, as supplemented in the 1st example of the gestalt of operation of this invention, photosensitive illumination-light IL1B is reflected in a photoresist in the reflector of deformation mirror 5B, and you may make it a configuration which makes a photoresist penetrate nonphotosensitivity illumination-light IL2B in the other part. What is necessary is to prepare circular opening as a deformation mirror, so that illumination-light IL2B may penetrate in the center section, and just to use the deformation mirror which has a zona-orbicularis-like reflector to illumination-light IL1B which carries out incidence from the direction which intersects perpendicularly around the opening to illumination-light IL2B, while replacing light source section 1B, 2B, a reticle 10, up lens system 12A, and related arrangement of optical system in drawing 6 when making it such a configuration.

[0038] Next, the modification of the 2nd example of the gestalt of operation of this invention is explained with reference to drawing 7 . The configuration to the projection optics of the projection aligner of this modification is the same as that of the modification of the 1st example of drawing 4 almost (however, the aperture diaphragm 37 is excluded), gives the same sign to the part corresponding to drawing 4 and drawing 6 in drawing 7 , and omits the detail explanation. Drawing 7 showed the outline configuration of the projection aligner of this example, and arranges the aperture diaphragm 43 which has the same wavelength selection nature as the aperture diaphragm 37 of drawing 5 (a) near the pupil surface PS between up lens system 12A of projection optics 12, and lower lens system 12B in this drawing 7 . Illumination-light IL1A of the photosensitive wavelength lambda 1 is compounded by the polarization beam splitter 31, it penetrates a reticle 10 to the photoresist injected by the photoresist injected from light source section 2A from illumination-light IL2A of the nonphotosensitivity wavelength lambda 2, and light source section 1A, and the Fourier transform is optically carried out to it by up lens system 12A of projection optics 12, and it carries out incidence to it at an aperture diaphragm 43. The light filter of the shape of zona orbicularis which penetrates only photosensitive illumination-

light IL1A, and the circular light filter which penetrates only nonphotosensitivity illumination-light IL2A to a photoresist by the inside are formed in the photoresist like drawing 5 (a), and an aperture diaphragm 43 acts on an aperture diaphragm 43 as a pupil filter of a main protection-from-light mold to illumination-light IL1A. After another illumination-light IL2A passes through the circular field where illumination-light IL1A was shaded, incidence of it is carried out on a wafer 13 through lower lens system 12B.
[0039] In this modification, high resolution is obtained like the example of drawing 6 by the aperture diaphragm 43 arranged at the pupil surface PS of projection optics 12. Moreover, since the ** material of lower lens system 12B is illuminated by two illumination-light IL1A and IL2A by uniform illumination distribution, high order spherical-aberration fluctuation is suppressed. In addition, as a light filter which penetrates illumination-light IL1A from light source section 1A, the light filter which does not penetrate illumination-light IL2A from light source section 2A as much as possible has the greatly desirable effectiveness of reducing high order aberration. In addition, like the example of drawing 4 , it may replace with a polarization beam splitter 31, and a dichroic mirror may be used.
[0040] Next, in the gestalt of above-mentioned operation, the illumination distribution over the lens of projection optics 12 is equalized, and it explains that high order aberration fluctuation is suppressed based on the example of count. First, the temperature distribution after the rise by the exposure of the illumination light are calculated. When a lens is approximated to a cylindrical shape, and heat does not flow out of the side face of a lens through surrounding air but the edge of a lens touches a metal, only from the edge, it flows out and the absorbed energy density distribution in a lens sets heat constant to the surrounding include angle of an optical axis AX. The temperature distribution after r, then a rise are set to function [of Variable r] T (r) in the variable showing a radial distance of the lens, and when the absorbed duty and thermal conductivity per unit volume of a lens are set to omega (r) and lambda, respectively and the circumradius of a lens is set to a, the heat conduction equation in the cylindrical coordinate system in a thermal equilibrium state can be expressed like a degree type.
[0041]
[Equation 1] ** -- 2 T/**r2+(1/r) **T/** r+omega (r) / lambda= 0 -- if this heat conduction equation is solved, it will become like a degree type.
[0042]
[Equation 2]

$$T(r)=\sum_{i=1}^{\infty} B_i J_0 (p_i \cdot r)$$

[0043] Here, Jn (pi and r) is the n-th 1st sort bessel (Bessel) function (n= 0, 1 and 2, --), and is pi. It is the sequence of numbers with which J1(pi and a) =0 is filled (i= 1, 2 and 3, --). Moreover, multiplier Bi It asks by the degree type.
[0044]
[Equation 3]

$$B_i=2\int_0^a \omega(r)\ J_0(p_i \cdot r)\ r\,dr / \{\lambda p_i^2 a^2 [J_1(p_i \cdot a)]^2\}$$

[0045] It sets at the section when Variable r fills hj <=r<=hj +1 in certain j (1 <=j<=N) when an absorbed duty omega (r) is especially expressed with a stair-like function within the radius (exposure radius) of an exposure field, and an absorbed duty omega (r) is constant value omega j. The following relation is materialized when taking.
[0046]
[Equation 4]

$$\int_0^a \omega(r)\, J_0(p_i \cdot r)\, r\,dr = \sum_{j=1}^{N} \int_0^a \omega_j \cdot J_0(p_i \cdot r)\, r\,dr$$

$$= \sum_{j=1}^{N} \omega_j \{h_{j+1} \cdot J_1(p_i \cdot h_{j+1}) - h_j \cdot J_1(p_i \cdot h_j)\} / p_i$$

[0047] Therefore, it is a multiplier Bi by substituting (several 4) for (several 3). It asks and is this multiplier Bi. By substituting for (several 2), temperature-distribution [after a rise] T (r) is called for. Next, if the BEKI expansion into series of the temperature-distribution [after a rise] T (r) is carried out to the term of r10 with the least square method as follows in order for temperature-distribution [after a rise] T (r) to investigate of which degree aberration fluctuation appears mostly, it will become like a degree type.
[0048]
[Equation 5] T(r) =T0+C2, r2+C4, r4+C6, r6+C8 and r8+C10, and r10 -- the unit of ** and Variable r of the unit of temperature-distribution [after a rise] T (r) is mm in this case. Moreover, T0 An optical axis AX r, i.e., a variable, is temperature-distribution [after the rise in the location of 0] T (0).
[0049] Hereafter, the example of count based on an actual numeric value is explained. The value (coherence factor) of the ratio of the numerical aperture by the side of the outgoing radiation of the illumination-light study system to the numerical aperture by the side of the incidence of projection optics (NA) is made into a sigma value, and this sigma value is set as 0.75. And the lens which a sigma value becomes from the quartz of the cylindrical shape of 40mm of circumradii according to the illumination system of 0.75 is illuminated, and it calculates based on the solution of the heat conduction equation of - (several 2) (several 4) about a case so that the radius d of the exposure field on a lens may be 30mm. The heat conductivity of a quartz is made into 0.0138W/(cmand**), and the rate of heat absorption of the lens to the photosensitive illumination light is made the photoresist on a wafer in 2%/cm.
[0050] In the 1st example of count, a sigma value calculates [the total amount of exposure energy of the illumination light / a lens] about the case where it irradiates uniformly, within the limits of 0.75 by 1W first for a comparison. Drawing 8 (a) shows temperature-distribution [after the rise by the 1st example of count] T (r), an axis of abscissa expresses Variable r and an axis of ordinate expresses temperature-distribution [after a rise] T (r). As shown in curvilinear 46A of a continuous line, temperature-distribution [after a rise] T (r) has maximum at Zero AX, i.e., an optical axis, and shows a crest type change symmetrical with a shaft to it about an optical axis AX. In addition, dotted-line 47A shows exposure energy density [of the illumination light] P (r) as reference. Exposure energy density P (r) becomes the value P1 with r fixed among Variables0-d (exposure radius). Moreover, the coefficient C 2 when developing the temperature distribution T0 in an optical axis AX and temperature-distribution T (r) to BEKI series by (several 5) - C10 are shown in Table 1.
[0051]
[Table 1]

光軸における上昇後の温度分布T_0	1.8182×10^{-1}
係数	
C_2	-1.3450×10^{-4}
C_4	4.4000×10^{-8}
C_6	-9.9006×10^{-11}
C_8	8.2983×10^{-14}
C_{10}	-2.0745×10^{-17}

[0052] Next, the 2nd example of count is explained. This example of count is an example when only zona-orbicularis lighting is performed, and is an example of count for a comparison as well as the 1st example of count. A sigma value is 0.75 at the maximum, and the sigma value inside the zona orbicularis is 0.5. A lens is uniformly illuminated for the sigma value between 0.5-0.75, and temperature-distribution [after a rise] T (r) is calculated about the case where the total amount of exposure energy is 1W.
[0053] Drawing 4 (b) shows temperature-distribution [after the rise by the 2nd example of count] T (r), and in this drawing 4 (b), as shown in curvilinear 46B of a continuous line, as for temperature-distribution [after a rise] T (r), Variable r serves as the fixed rise temperature TB between about 0 - e. Variable r serves as the fixed value P2 between e-d, and, as for exposure energy density P (r) shown by dotted-line 47B, r has become 0 among Variables0-e. The coefficient C 2 when developing the temperature distribution T0 after a rise with an optical axis AX and temperature-distribution [after a rise] T (r) to BEKI series by (several 5) - C10 are shown in Table 2 like the 1st example of count.
[0054]
[Table 2]

光軸における上昇後の温度分布T$_0$	1.0744×10^{-1}
係数	
C_2	-3.4321×10^{-5}
C_4	2.7328×10^{-7}
C_6	-6.3961×10^{-10}
C_8	4.5319×10^{-13}
C_{10}	-1.0513×10^{-16}

[0055] Next, the 3rd example of count is explained. This example of count asks the photoresist on a wafer 13 for temperature-distribution [after a rise in case the lens is illuminated by two illumination light of the nonphotosensitivity illumination light] T (r) at the photosensitive illumination light and its photoresist like the gestalt of operation shown in drawing 1 , drawing 4 , drawing 6 , and drawing 7 . In this case, within the limits of 0.75 to 0.5, a lens shall be uniformly illuminated for the total amount of exposure energy by the photoresist by 1W by the illumination light of photosensitivity [sigma value], and the lens shall be illuminated so that a sigma value may become [a sigma value / exposure energy density P (r)] a photoresist from 0.5 by the illumination light of nonphotosensitivity wavelength within the limits of 0.0 one half of the exposure energy density in the range of 0.75 to 0.5.
[0056] Drawing 4 (c) shows temperature-distribution [after the rise by the 3rd example of count] T (r), and as this drawing 4 (c) is shown in curvilinear 46C of a continuous line, temperature-distribution [after a rise] T (r) has Maximum TC at Zero AX, i.e., an optical axis, and it shows a crest type change symmetrical with a shaft about an optical axis AX. Moreover, Variable r serves as the fixed value P2 between e-d, and exposure energy density P (r) has become the value P3 (=P2/2) with r fixed among Variables0-e, as shown in dotted-line 47C which changes stair-like. Moreover, the coefficient C 2 when developing the temperature distribution T0 in an optical axis AX and temperature-distribution T (r) to BEKI series by (several 5) - C10 are shown in Table 3.
[0057]
[Table 3]

光軸における上昇後の温度分布T_0	2.1736×10^{-1}
係数 C_2 C_4 C_6 C_8 C_{10}	 -1.3821×10^{-4} 1.7624×10^{-7} -4.0891×10^{-10} 3.0128×10^{-13} -7.1235×10^{-17}

[0058] In addition, in the 1st and 2nd examples of count, the total amount of exposure energy is set to 1W, it sets for the 3rd example of count, and the sigma value is setting the amount of exposure energy of 0.75 to 0.5 within the limits to 1W. In this 3rd example of count, if a sigma value applies the amount of exposure energy in the range of 0.5-0.0, the total amount of exposure energy will exceed 1W. This makes equal the amount of exposure energy of the photosensitive illumination light at the photoresist on the 1st - the wafer 13 in the 3rd example of count, and it sets it up so that the exposure time (throughput) may become equal.

[0059] When the lighting gestalt (uniform lighting) shown in the 1st example of count is compared with the lighting gestalt (zona-orbicularis lighting) shown in the 2nd example of count, as shown in Table 1 and 2, as compared with uniform lighting, rise temperature [in / in the direction of zona-orbicularis lighting / an optical axis AX] is low. Nevertheless, coefficient C 4 of BEKI series When it compares, it is the coefficient C 4 in uniform lighting. A value is the coefficient C 4 in zona-orbicularis lighting to 4.4000x10-8. 2.7328x10-7 and the direction of zona-orbicularis lighting are large. That is, when uniform lighting is compared with zona-orbicularis lighting, it is a coefficient C 2. As for all the absolute values of the multiplier of the BEKI series of an except, the direction of zona-orbicularis lighting is large. Since heat deformation and refractive-index change are proportional to temperature-distribution [after a rise] T (r), it is proportional to temperature-distribution [after aberration fluctuation also going up] T (r). Coefficient C 2 That the zona-orbicularis lighting is larger means that the aberration fluctuation with the higher order zona-orbicularis lighting is large in all the multipliers of high order BEKI series.

[0060] If the lighting gestalt in the gestalt of operation shown in drawing 1 , drawing 4 , drawing 6 , and drawing 7 is considered as "synthetic lighting" here Although there are more total exposures than uniform lighting or zona-orbicularis lighting as shown in the 3rd example of count when the illumination light is irradiated also near the optical axis with synthetic lighting As shown in Table 1 and 2, it is a coefficient C 4. A value (= 1.7624x10-7) is the coefficient C 4 in zona-orbicularis lighting. It is smaller than a value (= 2.7328x10-7). Furthermore, if a coefficient C 6 and the absolute value of C8 and C10 are compared, also in which multiplier, the direction of synthetic lighting is smaller than zona-orbicularis lighting. This means that high order aberration fluctuation becomes small with synthetic lighting.

[0061] Moreover, although it set for the 3rd example of count and the sigma value set sigma value's exposure energy density between 0-0.5 to one half of the density distribution between 0.5-0.75, it calculates about temperature-distribution [when the sigma value is altogether irradiated by uniform exposure energy distribution in the range of 0-0.75] T (r), and compares with the case of the zona-orbicularis lighting of drawing 4 (b).

[0062] Between the energy density P1 of drawing 8 (a), and the exposure energy density P2 of drawing 8 (b), the relation between P2=1.8 and P1 is materialized. Therefore, in zona-orbicularis lighting like drawing 8 (b), when a sigma value also irradiates less than 0.5 range with exposure energy density equal to a zona-orbicularis lighting field, in drawing 8 (a), it is equivalent to the condition of having doubled exposure energy density 1.8. Therefore, the coefficient C 4 in Table 1 since all the multipliers of BEKI series are also doubled 1.8, and C6, C8 and C10 are 7.9200x10-8, -1.7821x10-10, 1.4937x10-13, and -3.7341x10-17, respectively. It becomes. When the value of these multipliers is compared with each multiplier of Table 2, they are the temperature distribution T0 after the rise near the optical-axis AX. In

spite of being quite larger than the case where it is zona-orbicularis lighting, the multiplier to a coefficient C 4 - C10 is small altogether from the case of zona-orbicularis lighting. That is, even when a sigma value irradiates within the limits of 0-0.75 with synthetic lighting with the same exposure energy density P2 as zona-orbicularis lighting, aberration fluctuation higher order than the case of zona-orbicularis lighting means few things.

[0063] In addition, although the gestalt of above-mentioned operation applies this invention to the projection aligner of a stepper mold, this invention is applicable also to the projection aligner of a scan exposure mold like step - and - scanning method. In addition, of course, configurations various in the range which this invention is not limited to the gestalt of above-mentioned operation, and does not deviate from the summary of this invention can be taken.

[0064]

[Effect of the Invention] In order to use the illumination light for the exposure from the light source distributed over the field which carried out eccentricity from the optical axis on the pupil surface of projection optics, and the field [****] according to the 1st projection aligner of this invention, the effectiveness of the same improvement in resolution as the case where zona-orbicularis lighting or deformation lighting is performed is acquired. Moreover, since the nonphotosensitivity illumination light is irradiated, high order heat deformation and refractive-index change of the lens of projection optics decrease, and the advantage on which high order spherical-aberration fluctuation of projection optics is suppressed is in the field through which the illumination light for exposure does not pass when performing zona-orbicularis lighting and deformation lighting.

[0065] Moreover, when an illumination-light study system illuminates a mask by the illumination light for the exposure from the zona-orbicularis-like light source or two or more light sources in the location which carried out eccentricity to the optical axis, high resolution is obtained by the so-called zona-orbicularis lighting and deformation lighting. Moreover, an illumination-light study system has an optical integrator for equalizing the illuminance distribution of the illumination light for exposure, in preparing the fill-in flash induction material which leads the illumination light from an auxiliary illumination system to a mask between an optical integrator and a mask, where the illumination light for exposure and the nonphotosensitivity illumination light are correctly separated on a pupil surface and a field [****], a mask can be illuminated, and there is an advantage to which an image formation property does not deteriorate.

[0066] Moreover, in order to use the image formation flux of light which passes through the field which carried out eccentricity from the optical axis on the pupil surface of projection optics by the optical member which has wavelength selection nature according to the 2nd projection aligner of this invention, there is an advantage from which the same resolution as the case where the pupil filter of a main zona-orbicularis-like protection-from-light mold is installed is obtained. Furthermore, the lens near the pupil surface of projection optics has the advantage to which the high order fluctuation component of heat deformation of a lens or a refractive index decreases since it irradiates by uniform illumination distribution by two illumination light of the illumination light for exposure, and the illumination light of nonphotosensitivity [substrate / sensitization], and high order spherical-aberration fluctuation of projection optics decreases.

[Translation done.]

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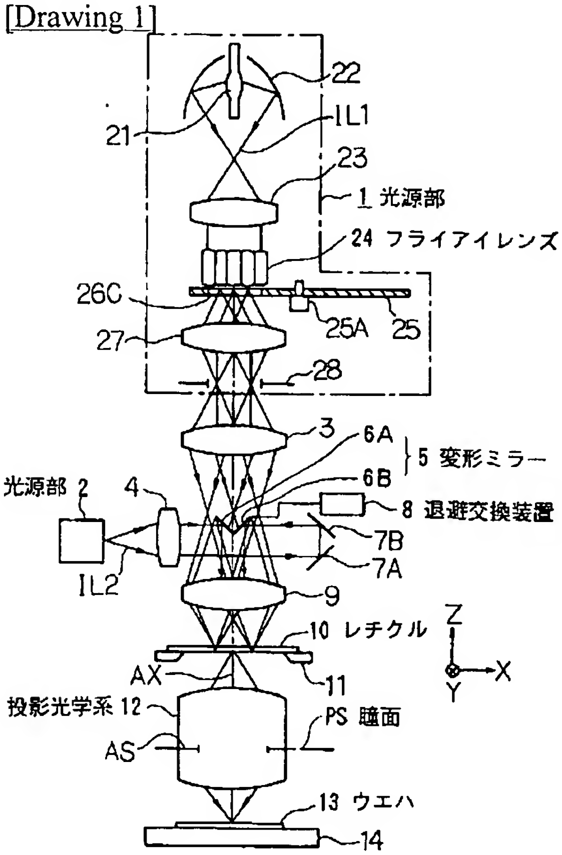
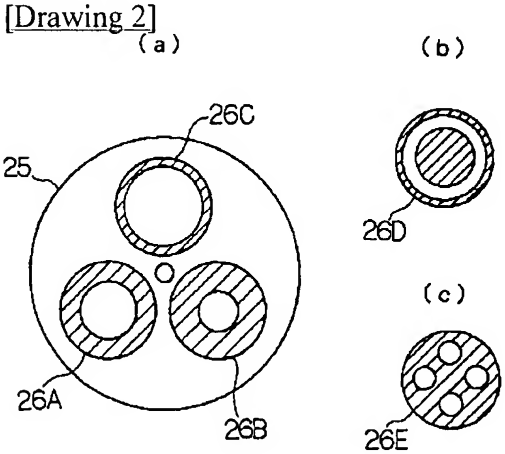
1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DRAWINGS

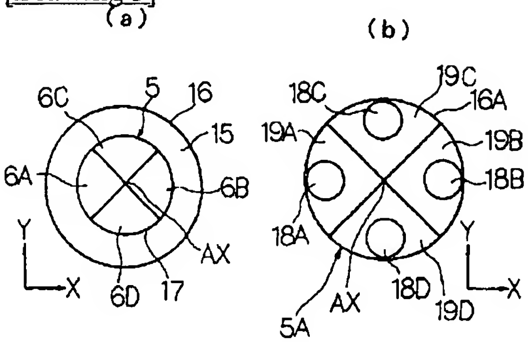
[Drawing 1]



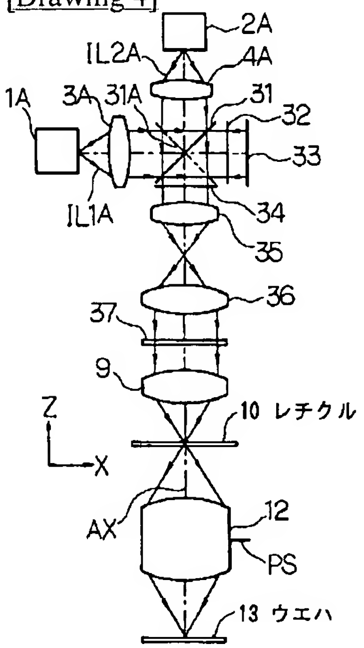
[Drawing 2]



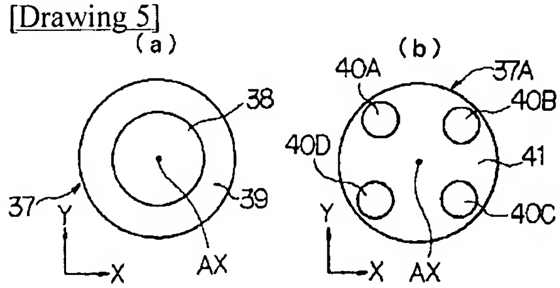
[Drawing 3]



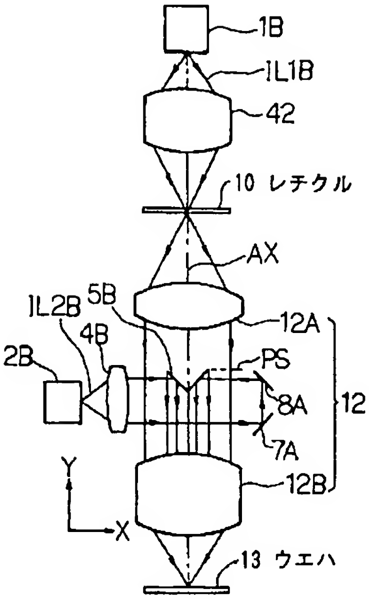
[Drawing 4]



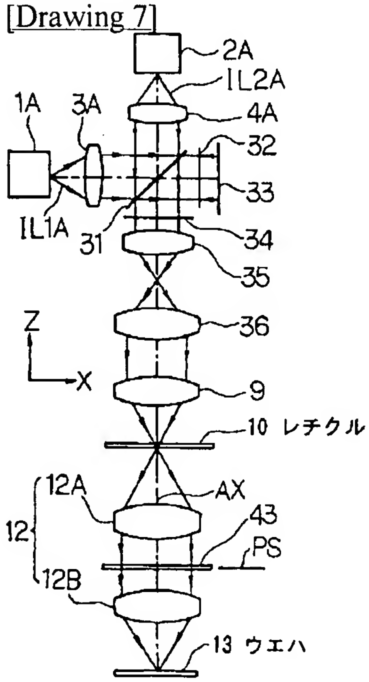
[Drawing 5]



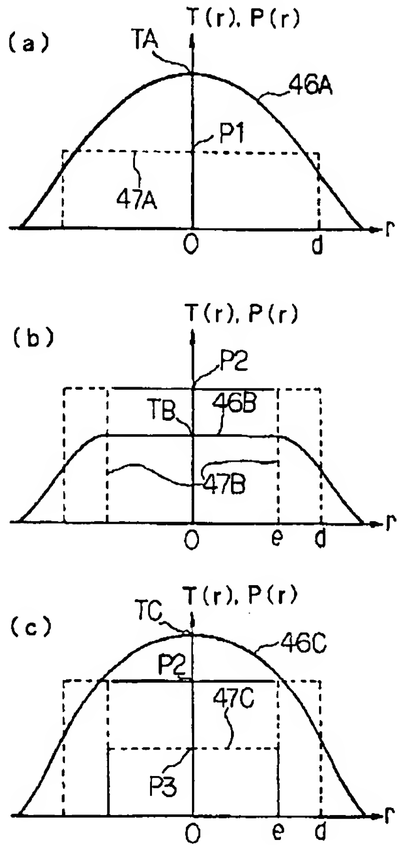
[Drawing 6]



[Drawing 7]



[Drawing 8]



[Translation done.]

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[Method of Amendment] Modification
[The contents of amendment]
[Title of the Invention] The projection exposure approach and equipment
[Procedure amendment 2]
[Document to be Amended] Specification
[Item(s) to be Amended] Claim
[Method of Amendment] Modification
[The contents of amendment]
[Claim(s)]
[Claim 1]
Projection optics which projects the image of the pattern on a mask on a sensitization substrate under the illumination light for exposure,
In the projection aligner which has the illumination-light study system which illuminates said mask using the illumination light for said exposure from the light source distributed over the field which carried out eccentricity from an optical axis on the pupil surface of said projection optics, and a field [****],

The projection aligner characterized by establishing the auxiliary illumination system which irradiates the illumination light of a nonphotosensitivity wavelength region to the field through which the illumination light for said exposure does not pass on the pupil surface of said projection optics to said sensitization substrate.
[Claim 2]
It is a projection aligner according to claim 1,
Said illumination-light study system is a projection aligner characterized by illuminating said mask by the illumination light for said exposure from the zona-orbicularis-like light source or two or more light sources in the location which carried out eccentricity to the optical axis.
[Claim 3]
It is a projection aligner according to claim 1 or 2,
Said illumination-light study system has an optical integrator for equalizing the illuminance distribution of the illumination light for said exposure,
The projection aligner characterized by preparing the fill-in flash induction material which leads the illumination light from said auxiliary illumination system to said mask between this optical integrator and said mask.
[Claim 4]
It is the projection aligner of claim 1-3 given in any 1 term,
The projection aligner characterized by preparing the fill-in flash induction material which draws the illumination light from said auxiliary illumination system between said masks and said images.
[Claim 5]
It is the projection aligner of claim 1-4 given in any 1 term,
Said projection optics is a projection aligner characterized by having a lens.
[Claim 6]
It is a projection aligner according to claim 5,
The illumination light from said auxiliary illumination system is a projection aligner characterized by setting up reinforcement according to the ** material of said lens, or the amount of light absorption in the coating film prepared in said lens.
[Claim 7]
It is a projection aligner according to claim 5 or 6,
Said lens is a projection aligner characterized by being formed with a quartz.
[Claim 8]
It is the projection aligner of claim 5-7 given in any 1 term,
Said auxiliary illumination system is a projection aligner characterized by irradiating the illumination light of said nonphotosensitivity wavelength region so that illumination distribution may become uniform to the lens near said pupil surface of said projection optics.
[Claim 9]
It is the projection aligner of claim 1-8 given in any 1 term,
Said illumination-light study system is a projection aligner characterized by changing distribution of said light source on said pupil surface of said projection optics, and a field [****].
[Claim 10]
It is a projection aligner according to claim 9,
Said illumination-light study system is a projection aligner characterized by switching the condition of distributing said light source over said field which carried out eccentricity from said optical axis on said pupil surface of said projection optics, and said field [****], and the condition of distributing said light source over the circular field centering on said optical axis on said pupil surface of said projection optics, and said field [****].
[Claim 11]
It is a projection aligner according to claim 9 or 10,
The projection aligner characterized by changing the field which irradiates the illumination light of said nonphotosensitivity wavelength region by said auxiliary illumination system according to modification

of distribution of said light source.
[Claim 12]
In the projection aligner using the image formation flux of light which passes through the field which carried out eccentricity from the optical axis on the pupil surface of said projection optics in case the image of the pattern on a mask is projected on a sensitization substrate through projection optics under the illumination light for exposure,
The synthetic illumination-light study system which leads the nonphotosensitivity illumination light to the pupil surface of said projection optics to the illumination light and said sensitization substrate for said exposure,
The projection aligner characterized by having the optical member which has the wavelength selection nature which passes only the nonphotosensitivity illumination light to said sensitization substrate side to said sensitization substrate in fields other than the field which it has been arranged on the pupil surface of said projection optics, and carried out eccentricity from said optical axis.
[Claim 13]
In the projection exposure approach which projects the image of the pattern on a mask on a sensitization substrate under the illumination light for exposure,
The 1st process which forms the light source in the field which carried out eccentricity from the optical axis on the pupil surface of the projection optics which forms the image of said pattern, and the field [****];
The 2nd process which illuminates said mask using the illumination light for said exposure from the light source distributed over the field which carried out eccentricity from said optical axis;
The 3rd process which irradiates the illumination light of a nonphotosensitivity wavelength region to said sensitization substrate to the field through which the illumination light for said exposure does not pass on said pupil surface of said projection optics;
The projection exposure approach characterized by preparation ******.
[Claim 14]
It is the projection exposure approach according to claim 13,
The projection exposure approach characterized by forming the zona-orbicularis-like light source or two or more light sources in the location which carried out eccentricity to said optical axis at said 1st process.
[Claim 15]
It is the projection exposure approach according to claim 13 or 14,
It has further the 4th process which equalizes the illumination distribution of the illumination light for said exposure using an optical integrator,
The projection exposure approach characterized by irradiating the illumination light of said nonphotosensitivity wavelength region from between said optical integrators and said masks at said 3rd process.
[Claim 16]
It is the projection exposure approach according to claim 13 or 14,
The projection exposure approach characterized by irradiating the illumination light of said nonphotosensitivity wavelength region from between said masks and said images at said 3rd process.
[Claim 17]
It is the projection exposure approach of claim 13-16 given in any 1 term,
Said projection optics is the projection exposure approach characterized by having the lens.
[Claim 18]
It is the projection exposure approach according to claim 17,
The projection exposure approach characterized by irradiating the illumination light of said nonphotosensitivity wavelength region so that illumination distribution may become uniform to the lens near said pupil surface of said projection optics at said 3rd process.
[Claim 19]
It is the projection exposure approach of claim 13-18 given in any 1 term,

The projection exposure approach characterized by changing distribution of said light source on said pupil surface of said projection optics, and a field [****] at said 1st process.
[Claim 20]
It is the projection exposure approach according to claim 19,
The projection exposure approach characterized by switching the condition of forming said light source in said field which carried out eccentricity from said optical axis on said pupil surface of said projection optics, and said field [****] at said 1st process, and the condition of forming said light source in the circular field centering on said optical axis on said pupil surface of said projection optics, and said field [****].
[Claim 21]
It is the projection exposure approach according to claim 19 or 20,
The projection exposure approach characterized by having further the process which changes the field which irradiates the illumination light of said nonphotosensitivity wavelength region by said auxiliary illumination system according to modification of distribution of said light source.
[Procedure amendment 3]
[Document to be Amended] Specification
[Item(s) to be Amended] 0007
[Method of Amendment] Modification
[The contents of amendment]
[0007]
In case this invention is exposed in view of this point using the pupil filter which shades near an optical axis, using zona-orbicularis lighting, deformation lighting, etc., it aims at offering the projection exposure approach and equipment with which high order spherical-aberration fluctuation of projection optics is suppressed, and high resolution is obtained.
[Procedure amendment 4]
[Document to be Amended] Specification
[Item(s) to be Amended] 0010
[Method of Amendment] Modification
[The contents of amendment]
[0010]
In this case, as for that illumination-light study system, it is desirable to illuminate that mask (10) by the illumination light for that exposure from the zona-orbicularis-like light source or two or more light sources in the location which carried out eccentricity to the optical axis (IL1). This means the illumination by the so-called zona-orbicularis lighting and deformation lighting, and, thereby, high resolution is obtained.
Moreover, as for that illumination-light study system, it is desirable to have an optical integrator (24) for equalizing the illuminance distribution of the illumination light for that exposure (IL1), and to prepare the fill-in flash induction material (4, 6A-6D, 7A, 7B) which leads the illumination light (IL2) from that auxiliary illumination system (2) to that mask (10) between this optical integrator and its mask (10). Thereby, the illumination light (IL1) and illumination light (IL2) for exposure are easily compoundable.
Moreover, the fill-in flash induction material (4B, 5B) which draws the illumination light from the auxiliary illumination system between the mask and its image may be prepared.
Moreover, the projection optics is equipped with the lens as an example.
Moreover, reinforcement may be set up according to the amount of light absorption in the coating film by which the illumination light from the auxiliary illumination system was prepared in the ** material of the lens, or its lens.
Moreover, the lens is formed with a quartz as an example.
Moreover, the auxiliary illumination system may irradiate the illumination light of the nonphotosensitivity wavelength region so that illumination distribution may become uniform to the lens near the pupil surface of the projection optics.
Moreover, the illumination-light study system may change distribution of the light source on the pupil

surface of the projection optics, and a field [****].
Moreover, you may make it the illumination-light study system switch the condition of distributing the light source over the field which carried out eccentricity from the optical axis on the pupil surface of the projection optics, and its field [****], and the condition of distributing the light source over the circular field centering on the optical axis on the pupil surface of the projection optics, and its field [****]. In this case, according to modification of distribution of that light source, the field which irradiates the illumination light of that nonphotosensitivity wavelength region by that auxiliary illumination system may be changed.
[Procedure amendment 5]
[Document to be Amended] Specification
[Item(s) to be Amended] 0012
[Method of Amendment] Modification
[The contents of amendment]
[0012]
In order to use the image formation flux of light which passes through the field which carried out eccentricity from the optical axis (AX) on the pupil surface (PS) of projection optics (12) according to the 2nd projection aligner of this this invention, it becomes using the pupil filter of a main protection-from-light mold substantially, and equivalence, and high resolution is obtained. In this case, by the optical member (5B), the illumination light for exposure (IL1B) passes only through fields, such as the shape of zona orbicularis, and the nonphotosensitivity illumination light (IL2B) passes through fields other than the field which carried out eccentricity from that optical axis to a sensitization substrate (13). Therefore, since the lens near the pupil surface (PS) of projection optics (12) is irradiated by two illumination light (IL1B, IL2B) by uniform illumination distribution, the high order fluctuation component in heat deformation of a lens or change of a refractive index decreases, and high order spherical-aberration fluctuation also decreases. And the nonphotosensitivity illumination light (IL2B) does not affect the projection image on a sensitization substrate (13).
Next, the projection exposure approach by this invention is set under the illumination light for exposure to the projection exposure approach which projects the image of the pattern on a mask on a sensitization substrate. As opposed to the sensitization substrate the 1st process which forms the light source in the field which carried out eccentricity from the optical axis on the pupil surface of the projection optics which forms the image of the pattern, and the field [****], and; -- the 2nd process which illuminates the mask using the illumination light for the exposure from the light source distributed over the field which carried out eccentricity from the optical axis, and; -- It has the 3rd process which irradiates the field to which the illumination light for the exposure does not pass the illumination light of a nonphotosensitivity wavelength region on the pupil surface of the projection optics.
In this invention, the zona-orbicularis-like light source or two or more light sources in the location which carried out eccentricity to the optical axis may be formed at the 1st process.
Moreover, it may have further the 4th process which equalizes the illuminance distribution of the illumination light for the exposure using an optical integrator, and the illumination light of the nonphotosensitivity wavelength region may be irradiated from between the optical integrator and its mask at the 3rd process.
Moreover, at the 3rd process, the illumination light of the nonphotosensitivity wavelength region may be irradiated from between the mask and its image.
Moreover, the projection optics is equipped with the lens as an example.
Moreover, at the 3rd process, the illumination light of the nonphotosensitivity wavelength region may be irradiated so that illumination distribution may become uniform to the lens near the pupil surface of the projection optics.
Moreover, at the 1st process, distribution of the light source on the pupil surface of the projection optics and a field [****] may be changed.
Moreover, you may make it switch the condition of forming the light source in the field which carried out eccentricity from the optical axis on the pupil surface of the projection optics, and its field [****],

and the condition of forming the light source in the circular field centering on the optical axis on the pupil surface of the projection optics, and its field [****], at the 1st process. In this case, according to modification of distribution of that light source, you may have further the process which changes the field which irradiates the illumination light of that nonphotosensitivity wavelength region by that auxiliary illumination system.

[Procedure amendment 6]

[Document to be Amended] Specification

[Item(s) to be Amended] 0064

[Method of Amendment] Modification

[The contents of amendment]

[0064]

[Effect of the Invention]

In order to use the illumination light for the exposure from the light source distributed over the field which carried out eccentricity from the optical axis on the pupil surface of projection optics, and the field [****] according to the 1st projection aligner and projection exposure approach of this invention, the effectiveness of the same improvement in resolution as the case where zona-orbicularis lighting or deformation lighting is performed is acquired. Moreover, since the nonphotosensitivity illumination light is irradiated, high order heat deformation and refractive-index change of the lens of projection optics decrease, and the advantage on which high order spherical-aberration fluctuation of projection optics is suppressed is in the field through which the illumination light for exposure does not pass when performing zona-orbicularis lighting and deformation lighting.

[Translation done.]

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ＧＯ３Ｆ　7/20	５２１		ＧＯ３Ｆ　7/20	５２１
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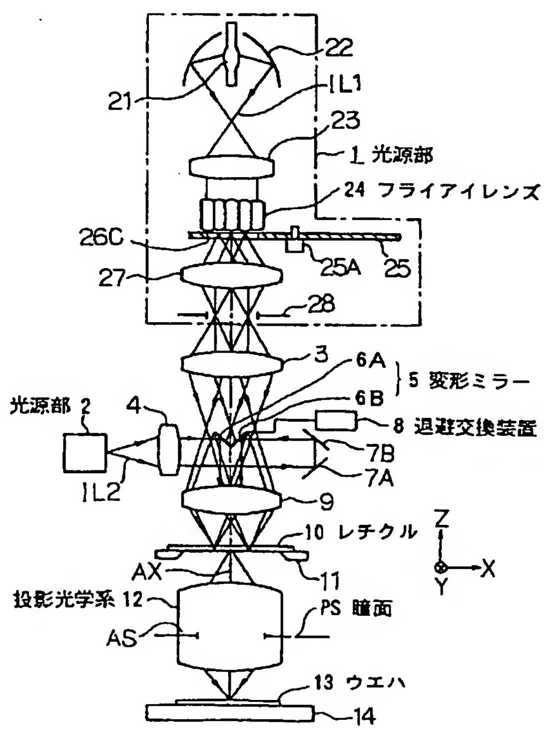
(54)【発明の名称】　投影露光装置

(57)【要約】

【課題】　輪帯照明や変形照明を行った場合の高次の球面収差変動を抑える。

【解決手段】　露光用の光源部１とは別にウエハ１３上のフォトレジストを感光しない波長の照明光ＩＬ２を射出する光源部２を設ける。光源部１とレチクル１０との間の照明光ＩＬ１の光路上に、レチクル１０側に傾斜した反射面を有するミラー６Ａ，６Ｂからなる変形ミラー５を設ける。光源部１からの露光用の照明光ＩＬ１は、変形ミラー５の周囲の輪帯状の領域を通過し、非露光用の照明光ＩＬ２は変形ミラー５の反射面で反射してレチクル１０及び投影光学系１２に向かう。その２つの照明光ＩＬ１，ＩＬ２により投影光学系１２の瞳面付近のレンズを均一な照度分布で照明する。



【特許請求の範囲】

【請求項１】　露光用の照明光のもとでマスク上のパターンの像を感光基板上に投影する投影光学系と、
前記投影光学系の瞳面と共役な面上で光軸から偏心した領域に分布する光源からの前記露光用の照明光を用いて前記マスクを照明する照明光学系と、を有する投影露光装置において、
前記感光基板に対して非感光性の波長域の照明光を前記投影光学系の瞳面上で前記露光用の照明光が通過しない領域に照射する補助照明系を設けたことを特徴とする投影露光装置。

【請求項２】　請求項１記載の投影露光装置であって、前記照明光学系は、輪帯状の光源、又は光軸に対して偏心した位置にある複数の光源からの前記露光用の照明光で前記マスクを照明することを特徴とする投影露光装置。

【請求項３】　請求項１、又は２記載の投影露光装置であって、
前記照明光学系は、前記露光用の照明光の照度分布を均一化するためのオプティカル・インテグレータを有し、該オプティカル・インテグレータと前記マスクとの間に、前記補助照明系からの照明光を前記マスクに導く補助光導入部材を設けたことを特徴とする投影露光装置。

【請求項４】　露光用の照明光のもとでマスク上のパターンの像を投影光学系を介して感光基板上に投影する際に、前記投影光学系の瞳面上で光軸から偏心した領域を通過する結像光束を用いる投影露光装置において、
前記露光用の照明光及び前記感光基板に対して非感光性の照明光を前記投影光学系の瞳面に導く合成照明光学系と、
前記投影光学系の瞳面上に配置され、前記光軸から偏心した領域以外の領域では前記感光基板に対して非感光性の照明光のみを前記感光基板側に通過させる波長選択性を有する光学部材と、を有することを特徴とする投影露光装置。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、例えば半導体素子、液晶表示素子、撮像素子（ＣＣＤ等）、又は薄膜磁気ヘッド等を製造するためのフォトリソグラフィ工程でマスク上のパターンの像を感光基板上に露光するために使用される投影露光装置に関し、特に輪帯照明等を行うか、又は中心遮光型の瞳フィルターを使用する投影露光装置に適用して好適なものである。

【０００２】

【従来の技術】従来、例えば半導体素子を製造する際に、マスクとしてのレチクル（又はフォトマスク等）のパターンの像を投影光学系を介して、感光基板としてのフォトレジストが塗布されたウエハ（又はガラスプレート等）上に転写するステッパー等の投影露光装置が使用されている。これらの投影露光装置では、ウエハにできるだけ高集積度のパターンを露光するため、露光光としてできるだけ短波長の照明光を使用すると共に、投影光学系の開口数（ＮＡ）を大きくして、転写されるパターンの解像度を上げるという努力がなされてきた。

【０００３】但し、単に投影光学系の開口数を大きくすると、焦点深度が狭くなりすぎるため、開口数にあまり依存することなく、或る程度以上の焦点深度を確保して、且つ高い解像度を得る方法として、露光光をレチクルに対して傾斜させて照明するという照明法が開発されている。この照明法には、照明光学系の２次光源の形状を輪帯状とする輪帯照明及びその２次光源の形状を光軸から偏心した複数（例えば４個）の小光源とする所謂変形照明等がある。このような照明法によれば、同じ露光波長、及び同じ投影光学系の開口数でも、投影光学系の解像度が向上する。また、投影光学系の瞳面に輪帯状等の瞳フィルターを配置して、所謂「超解像」により解像度を向上させる方法も開発されている。

【０００４】

【発明が解決しようとする課題】以上の従来技術において、輪帯照明等を使用せず、レチクルをレチクルに対して垂直に入射する光束を中心として一様に分布する露光光で照明する照明方法によれば、主にレチクルのパターンを通過した０次回折光、＋１次回折光、及び－１次回折光の３光束によってウエハ上にそのパターンの像を形成するために、投影光学系の瞳面付近のレンズは中心部も周辺部もほぼ一様に照明される。また、通常の照明法のもとで投影光学系の瞳面に中心部を遮蔽する輪帯状の瞳フィルターを配置しない場合も、投影光学系の瞳面の近くのレンズは一様に照明される。このような照明状態であれば、レンズの中心部が主に温度上昇するために、位置に関して２次以下の関数となる熱変形や屈折率変化が主に起こり、ガウス（Gauss）像面の移動だけが光軸付近の主な収差変動として生じる。従って、投影光学系の高次の球面収差変動が発生する恐れは少なかった。

【０００５】しかし、輪帯照明や変形照明法により照明を行った場合には、レチクルのパターンを通過した露光用の照明光の内の主に０次回折光及び１次回折光によってウエハ上にそのパターンの像を形成するため、投影光学系の解像度の限界線幅に近いパターンが多い場合には、投影光学系の光軸付近を透過する光線の量が周辺部に比べて極めて少なくなる。また、投影光学系の瞳面に光軸付近を遮光した瞳フィルターを配置した場合でも、瞳面よりもウエハに近い側に配置されているレンズの光軸付近を透過する光線の量は周辺部に比べて極めて少なくなる。

【０００６】このように投影光学系のレンズに対する照射エネルギーの分布が不均一になると、レンズの周辺部が主に熱を吸収して温度上昇し、中心部が温度上昇しないという現象が起こる。このような温度上昇に比例し

て、部分的にレンズの屈折率が変動したり、レンズが熱変形したりするので、２次よりも高次の非球面やそれに相当する屈折率分布が新たに形成される。そのため、投影光学系の光軸に近い部分では、露光光の照射によりガウス像面の移動だけでなく、新たに高次の球面収差変動が生じるという不都合があった。

【０００７】本発明は斯かる点に鑑み、輪帯照明や変形照明等を用いるか、又は光軸付近を遮光する瞳フィルターを使用して露光を行う際に、投影光学系の高次の球面収差変動を抑えて高い解像度が得られる投影露光装置を提供することを目的とする。

【０００８】

【課題を解決するための手段】本発明による第１の投影露光装置は、例えば図１に示すように、露光用の照明光（ＩＬ１）のもとでマスク（１０）上のパターンの像を感光基板（１３）上に投影する投影光学系（１２）と、その投影光学系の瞳面、即ちマスク（１０）のパターン面に対する光学的フーリエ変換面（ＰＳ）と共役な面上で光軸（ＡＸ）から偏心した領域に分布する光源（２次光源を含む）からのその露光用の照明光（ＩＬ１）を用いてそのマスク（１０）を照明する照明光学系（１，３，９）と、を有する投影露光装置において、その感光基板（１３）に対して非感光性の波長域の照明光（ＩＬ２）をその投影光学系（１２）の瞳面（ＰＳ）上でその露光用の照明光（ＩＬ１）が通過しない領域に照射する補助照明系（２）を設けたものである。

【０００９】斯かる本発明の第１の投影露光装置によれば、投影光学系（１２）の瞳面（ＰＳ）と共役な面上で光軸（ＡＸ）から偏心した領域に分布する光源からの露光用の照明光（ＩＬ１）を用いるとは、輪帯照明法や変形照明法を用いることを意味する。この際に、投影光学系（１２）の瞳面近傍のレンズは主に光軸から偏心した領域が露光用の照明光（ＩＬ１）により照明され、例えば所定の周期的パターンに対して高解像度が得られる。また、補助照明系により投影光学系（１２）の瞳面（ＰＳ）上で露光用の照明光（ＩＬ１）が通過しない領域、即ち光軸近傍の領域も感光基板に対して非感光性の照明光（ＩＬ２）で照明されるため、投影光学系（１２）の瞳面（ＰＳ）に近いレンズに対する照度分布が均一になり、レンズの熱変形や屈折率の変化における高次の変動成分が減少する。このためには、非感光性の照明光（ＩＬ２）は、露光用の照明光（ＩＬ１）と同程度の吸収率で投影光学系（１２）のレンズ、又はこのレンズのコーティング膜で吸収される必要がある。レンズの球面収差変動は、レンズの熱変形や屈折率の変化に比例するため、投影光学系（１２）の高次の球面収差変動が抑えられる。但し、補助照明系（２）からの照明光（ＩＬ２）は非感光性であるため、感光基板（１３）上に転写される像には影響がない。

【００１０】この場合、その照明光学系は、輪帯状の光源、又は光軸に対して偏心した位置にある複数の光源からのその露光用の照明光（ＩＬ１）でそのマスク（１０）を照明することが好ましい。これは、所謂輪帯照明や変形照明による照明法を意味し、これにより高い解像度が得られる。また、その照明光学系は、その露光用の照明光（ＩＬ１）の照度分布を均一化するためのオプティカル・インテグレータ（２４）を有し、このオプティカル・インテグレータとそのマスク（１０）との間に、その補助照明系（２）からの照明光（ＩＬ２）をそのマスク（１０）に導く補助光導入部材（４，６Ａ～６Ｄ，７Ａ，７Ｂ）を設けることが好ましい。これにより、露光用の照明光（ＩＬ１）と照明光（ＩＬ２）とを容易に合成できる。

【００１１】また、本発明による第２の投影露光装置は、例えば図６に示すように、露光用の照明光（ＩＬ１Ｂ）のもとでマスク（１０）上のパターンの像を投影光学系（１２）を介して感光基板（１３）上に投影する際に、その投影光学系（１２）の瞳面（ＰＳ）上で光軸（ＡＸ）から偏心した領域を通過する結像光束を用いる投影露光装置において、その露光用の照明光（ＩＬ１Ｂ）及びその感光基板（１３）に対して非感光性の照明光（ＩＬ２Ｂ）をその投影光学系の瞳面（ＰＳ）に導く合成照明光学系（１Ｂ，４２，２Ｂ，４Ｂ，７Ａ，８Ａ）と、その投影光学系（１２）のその瞳面（ＰＳ）上に配置され、その光軸から偏心した領域以外の領域ではその感光基板（１３）に対して非感光性の照明光（ＩＬ２Ｂ）のみをその感光基板側に通過させる波長選択性を有する光学部材（５Ｂ）と、を有するものである。

【００１２】斯かる本発明の第２の投影露光装置によれば、投影光学系（１２）の瞳面（ＰＳ）上で光軸（ＡＸ）から偏心した領域を通過する結像光束を用いるため、実質的に中心遮光型の瞳フィルターを用いるのと等価となって高い解像度が得られる。この場合、光学部材（５Ｂ）により、露光用の照明光（ＩＬ１Ｂ）は、輪帯状等の領域のみを通過し、感光基板（１３）に対して非感光性の照明光（ＩＬ２Ｂ）は、その光軸から偏心した領域以外の領域を通過する。従って、投影光学系（１２）の瞳面（ＰＳ）近傍のレンズは、２つの照明光（ＩＬ１Ｂ，ＩＬ２Ｂ）により均一な照度分布で照射されるため、レンズの熱変形や屈折率の変化における高次の変動成分が減少し、高次の球面収差変動も減少する。しかも、非感光性の照明光（ＩＬ２Ｂ）は感光基板（１３）上の投影像には影響を与えない。

【００１３】

【発明の実施の形態】以下、本発明の投影露光装置の実施の形態の第１の例につき図１～図３を参照して説明する。本例は、レチクル上のパターンを投影光学系を介してウエハ上の各ショット領域に投影するステッパー型の投影露光装置に本発明を適用したものである。

【００１４】図１は、本例の投影露光装置の概略構成を

示し、この図１に示すように本例の投影露光装置には３つの光源部（図１では２つの光源部１，２が現れている）が設けられている。露光時には、第１の光源部１からはウエハ１３上のフォトレジストに感光性の波長λ１の照明光ＩＬ１が射出され、第２の光源部２及び不図示の第３の光源部からはウエハ１３上のフォトレジストに非感光性の波長λ２の照明光ＩＬ２が射出される。光源部１の水銀ランプよりなる光源２１から射出された照明光は、楕円鏡２２によって第２焦点に集光した後、発散光となって、不図示の干渉フィルター等に入射し、干渉フィルターにより例えばｉ線（波長３６５ｎｍ）の照明光ＩＬ１が抽出される。次に、照明光ＩＬ１はインプットレンズ２３により平行光束となってオプティカルインテグレータとしてのフライアイレンズ２４に入射する。フライアイレンズ２４の各レンズエレメントの夫々の射出面には２次光源が形成され、これらの２次光源により面光源が作られる。フライアイレンズ２４の射出面には、面光源の大きさを調整するための切り換え自在の複数の開口絞り２６Ａ～２６Ｃ（図２（ａ）参照）が配置されている。これらの開口絞り２６Ａ～２６Ｃは、ターレット状の円板２５に固定され、円板２５を駆動装置２５Ａで回転することで所望の開口絞りをフライアイレンズ２４の射出面に設定できる。

【００１５】図２（ａ）は、図１の円板２５上の開口絞りの具体的な構成を説明するための平面図を示し、この図２（ａ）において、３個の開口絞り２６Ａ～２６Ｃはターレット状の円板２５の周辺に等角度間隔で固定されている。第１の開口絞り２６Ａは通常の照明を行う場合に使用される円形開口を有し、第２の開口絞り２６Ｂは小さいコヒーレンスファクタ（σ値）で照明を行う場合に使用される小さい円形開口を有する。第３の開口絞り２６Ｃは、大きな円形開口を有し、本例では輪帯照明、又は変形照明を行う場合にその第３の開口絞り２６Ｃをフライアイレンズ２４の射出面に設定する。即ち、通常輪帯照明時には図２（ｂ）に示す輪帯状の開口絞り２６Ｄが使用され、変形照明時には図２（ｃ）に示す光軸を中心として配置された４個の小さい開口を有する開口絞り２６Ｅが使用される。しかし、本例では後述の変形ミラー５等によって、実質的に開口絞り２６Ｄ等が兼用される。図１では第３の開口絞り２６Ｃが照明光ＩＬ１の光路上に配置されている。

【００１６】開口絞り２６Ｃを通過した照明光ＩＬ１は、第１リレーレンズ２７を透過し、視野絞り（レチクルブラインド）２８により照明範囲が規定される。照明範囲が規定された照明光ＩＬ１は、光源部１から射出されて第２リレーレンズ３を介して、照明光学系の光軸ＡＸを中心として第２リレーレンズ３側に凹の４角錐状に配置された４枚のミラー６Ａ～６Ｄ（図１ではその内の２枚のミラー６Ａ，６Ｂを示す）からなる変形ミラー５の周囲を通過する。変形ミラー５の４枚のミラーの反射面は外側を向き、照明光学系の光軸ＡＸに対してほぼ４５°傾斜している。更に、変形ミラー５の上面は、開口絞り２６Ｃの配置面に共役な位置に配置されている。変形ミラー５の周囲を通過した照明光ＩＬ１は、コンデンサレンズ９を経てレチクル１０に入射する。

【００１７】図３（ａ）は、図１の変形ミラー５をレチクル１０側からみた図を示し、この図３（ａ）において、ミラー６Ａ～６Ｄは互いに等しい形状で、照明光学系の光軸ＡＸを頂点とする４角錐を形成するように密接して配置されている。また、ミラー６Ａ～６Ｄの底面の外形１７は、全体として光軸ＡＸを中心とする１つの円周を形成している。そして、その外形１７と図１の開口絞り２６Ｃの開口の像の外周１６との間の輪帯状の領域１５を照明光ＩＬ１が通過するように構成されている。即ち、本例の変形ミラー５は、輪帯状の開口絞りを兼用している。

【００１８】図１に戻り、変形ミラー５は退避交換装置８によって照明光ＩＬ１の光路外に退避できると共に、別の変形ミラーと交換できるように構成されている。次に、第２の光源部２は非露光用の光源、及びその光源からの光束を所定の拡がり角で放出するレンズ系等を含んで構成されている。そして、レチクル１０の左上部に配置された光源部２から射出されたフォトレジストに非感光性の照明光ＩＬ２は、リレーレンズ４により平行光束にされ、一部が照明光学系の光軸ＡＸと直交する方向から変形ミラー５中のミラー６Ａに入射する。照明光ＩＬ２の一部はミラー６Ａにより下方に向けて反射される。ミラー６Ａの下方を通過した照明光ＩＬ２は、ミラー７Ａ，７Ｂにより反射されて変形ミラー５中のミラー６Ｂに入射し、ミラー６Ｂにより反射された光束は、ミラー６Ａで反射された光束と共にコンデンサレンズ９に入射する。不図示であるが、光源部２、リレーレンズ４、及びミラー７Ａ，７Ｂよりなる光学系と同様の光学系は図１の紙面に垂直な方向にも配置されており、この図１の紙面に垂直な方向に配置された第３の光源部からのフォトレジストに非感光性の照明光（これも照明光ＩＬ２とする）は、変形ミラー５中のミラー６Ｃ，６Ｄ（図３参照）により下方に反射される。従って、照明光ＩＬ２は、図３（ａ）において照明光ＩＬ１が通過する輪帯状の領域１５の内側の円形の領域で反射される。

【００１９】図１において、変形ミラー５の周囲を通過した照明光ＩＬ１、及び変形ミラー５により反射された照明光ＩＬ２は、共にコンデンサレンズ９によりレチクル１０上に照射される。レチクル１０上に照射された照明光ＩＬ１，ＩＬ２は、レチクル上のパターン領域を通過し、投影光学系１２を介してウエハ１３上に照射される。露光用の照明光ＩＬ１のもとで、投影光学系１２に関してレチクル１０のパターン面とウエハ１３の表面とは共役であり、照明光ＩＬ２は、ウエハ１３上のフォトレジストに非感光性であるため、その露光用の照明光Ｉ

Ｌ１により照明されたレチクル１０上のパターン像だけがウエハ１３上のフォトレジストを感光させる。この場合、投影光学系１２内の瞳面ＰＳ、即ちレチクル１０のパターン面に対する光学的フーリエ変換面は開口絞り２６Ｃの配置面ひいては変形ミラー５の上面と共役であり、瞳面ＰＳには開口絞りＡＳが配置されている。

【００２０】照明光ＩＬ１の波長λ１及び照明ＩＬ２の波長λ２は、フォトレジストの種類及び投影光学系１２のレンズを形成する硝材の種類等により異なるが、通常の場合、波長λ１は５３０ｎｍ未満、波長λ２は５３０ｎｍ以上の波長を選択する。露光用の照明光ＩＬ１としては、本例では水銀ランプのｉ線が使用されているが、それ以外に水銀ランプのｇ線（波長４３６ｎｍ）等の輝線、ＡｒＦエキシマレーザ光（波長１９３．２ｎｍ）やＫｒＦエキシマレーザ光（波長２４８．５ｎｍ）、あるいは銅蒸気レーザやＹＡＧレーザの高調波等が使用できる。また、照明光ＩＬ２としては、フォトレジストを感光させない波長で、レンズの硝材又はコーティング膜での単位面積当たりの光吸収量が全体として照明光ＩＬ１に近いものが好ましい。その意味から、照明光ＩＬ２としては、光吸収率が小さいときには光源の光強度が強く、一方光源の光強度が小さいときには、投影光学系１２のレンズの硝材又はコーティング膜に対する光吸収率のできるだけ大きなものが好ましい。照明光ＩＬ２の一例としては、例えばＨｅ－Ｎｅレーザからのレーザビーム（波長６３３ｎｍ）等が挙げられる。

【００２１】なお、投影光学系のレンズ用の硝材として、石英や紫外域から近赤外域までの透過率が良好な所定のガラスが使用された場合、これらの硝材は、約２μｍ以上の長い波長からかなりの光吸収率を有するので、照明光ＩＬ２として、フッ化水素（ＨＦ）ガスの化学反応を利用したＨＦ化学レーザ光（波長２．４～３．４μｍ）等を使用してもよい。また、石英以外の光学ガラスは、不純物を含んでいるため、５３０ｎｍ以上の波長でも１％／ｃｍに近い光吸収率を有するものもあり、このような１％／ｃｍに近い光吸収率を有する照明光でも十分有効である。このような照明光の例としては、水素（H_2）放電管からのＣ線（波長６５６．３ｎｍ）やヘリウム（Ｈｅ）放電管からのｄ線（波長５８７．６ｎｍ）等が挙げられる。図１において、照明光学系の光軸ＡＸは投影光学系１２の光軸と合致しており、以下では光軸ＡＸに平行にＺ軸を取り、Ｚ軸に垂直な２次元平面上で図１の紙面に平行にＸ軸、図１の紙面に垂直にＹ軸を取って説明する。

【００２２】レチクル１０はＸ方向、Ｙ方向、及び回転方向に微動可能なレチクルステージ１１上に載置されている。レチクルステージ１０の位置は外部のレーザ干渉計（不図示）により精密に計測されており、そのレーザ干渉計の測定値に基づいてレチクルステージ１１の位置が制御されている。一方、ウエハ１３は不図示のウエハホルダを介してＸ方向、Ｙ方向、及びＺ方向にウエハを位置決めするウエハステージ１４上に載置され、ウエハステージ１４の位置は、外部のレーザ干渉計により精密に計測されており、その計測値に基づいてウエハステージ１４の位置が制御されている。ウエハステージ１４によりウエハ１３の各ショット領域の中心を投影光学系１２の露光中心に移動する動作と、露光動作とがステップ・アンド・リピート方式で繰り返されて、レチクル１０上のパターンの像がウエハ１３上の各ショット領域に転写される。

【００２３】次に、本例の投影露光装置の動作について説明する。本例では、先ず図１に示すように、大きな開口を有する開口絞り２６Ｃと、変形ミラー５とを組み合わせて露光用の照明光ＩＬ１で実質的に輪帯照明を行っているため、例えば所定の周期的なパターンに対して高い解像度が得られる。また、図３（ａ）に示すように、投影光学系１２の瞳面ＰＳとほぼ共役な面上で、フォトレジストに感光性の照明光ＩＬ１は輪帯状の領域１５を通過し、変形ミラー５の反射面により反射されたフォトレジストに非感光性の照明光ＩＬ２は、領域１５の内側の領域を通過する。このような照明状態で、照明光ＩＬ１，ＩＬ２を図１のレチクル１０を経て投影光学系１２に入射させると、投影光学系１２の瞳面ＰＳ上で、照明光ＩＬ１，ＩＬ２は全体として光軸ＡＸを中心とする円形領域内を通過する。従って、その瞳面ＰＳの付近の投影光学系１２のレンズは周辺部ばかりでなく中心部も熱エネルギーを吸収して温度上昇する。そのため、瞳面ＰＳ付近のレンズでは熱変形や屈折率変化の２次の変動成分の割合が高次の変動成分に対して大きくなる。投影光学系１２の球面収差変動は、瞳面ＰＳ付近のレンズの熱変形や屈折率の変化にほぼ比例するため、球面収差変動も２次の成分が多くなり、投影光学系１２の高次の球面収差変動が抑えられる。

【００２４】なお、図１では輪帯照明用の変形ミラー５を使用したが、本例では図２（ｃ）に示す変形照明用の開口絞り２６Ｅを兼用する４角錐状の変形ミラー５Ａ（図３（ｂ）参照）も用意されている。即ち、変形照明を行うときには、図１の退避交換装置８を介して変形ミラー５の代わりに変形ミラー５Ａを照明光ＩＬ１の光路上に設定する。

【００２５】図３（ｂ）は、変形照明用の変形ミラー５Ａを図１のレチクル１０側から見た図を示し、この図３（ｂ）において、変形ミラー５Ａを構成する４個のミラー１９Ａ～１９Ｄは互いに等しい扇状で、光軸ＡＸを頂点とするレチクル１０に凸面を向けた４角錐を形成するように密接して配置されている。また、ミラー１９Ａ～１９Ｄはレチクル１０側の面が反射面となっており、ミラー１９Ａ～１９Ｄのレチクル１０から見た外形は全体として光軸ＡＸを中心とする１つの円周１６Ａとなっている。この円周１６Ａは、図３（ａ）の照明光ＩＬ１が

通過する円形の領域の外周１６とほぼ等しい。また、各ミラー１９Ａ～１９Ｄの外形の円周１６Ａの内側に等角度間隔で、レチクル１０側から見て円形の透過部１８Ａ～１８Ｄが形成され、この透過部１８Ａ～１８Ｄを図１の露光用の照明光ＩＬ１が透過するように構成されている。この変形ミラー５Ａが、図２（ｃ）の変形照明用の開口絞り２６Ｅを兼用している。

【００２６】即ち、本例で変形照明を行うときには、図１の退避交換装置８を介して、図１の変形ミラー５の代わりに変形ミラー５Ａを角錐の頂点が光軸ＡＸに一致するように、且つその頂点をレチクル１０側に向けて配置する。これによって、照明光ＩＬ１は４個の透過部１８Ａ～１８Ｄを透過して図１のレチクル１０上に照射される。一方、非露光用の照明光ＩＬ２は、図３（ｂ）の円周１６Ａ内で透過部１８Ａ～１８Ｄを除く領域で反射されてレチクル１０上に照射される。変形ミラー５Ａの上面は投影光学系１２の瞳面ＰＳと共役であるため、投影光学系１２の瞳面ＰＳ上では、光軸ＡＸを中心とする円形の領域が照明光ＩＬ１及びＩＬ２によって照明される。従って、変形照明法で高い解像度が得られると共に、高次の球面収差変動が抑えられる。しかも、非露光用の照明光ＩＬ２は結像特性には悪影響を与えない。また、図１において、通常の照明法を用いるときには、退避交換装置８を介して変形ミラー５，５Ａを照明光ＩＬ１の光路から退避させて、開口絞りとして図２（ａ）の開口絞り２６Ａ，２６Ｂを設定すればよい。

【００２７】なお、図３（ａ）又は図３（ｂ）の変形ミラー５，５Ａの反射面でフォトレジストに感光性の照明光ＩＬ１を反射し、フォトレジストに非感光性の照明光ＩＬ２の一部を遮光するような構成にしてもよい。このような構成にする場合は、図１において、光源部１，２及び関連する光学系の配置を入れ換えると共に、例えば図３（ａ）の変形ミラー５の代わりに、中央部に照明光ＩＬ２が透過するように円形の透過部を設け、その透過部の周辺に照明光ＩＬ２に対して直交する方向から入射する照明光ＩＬ１を反射する輪帯状の反射面を有する変形ミラーを使用すればよい。

【００２８】次に、本発明の実施の形態の第１の例の変形例について、図４を参照して説明する。本変形例は、露光用の照明光とフォトレジストに非感光性の照明光とを予め合成し、その合成光をレチクル１０の手前に設けた波長選択性を有する開口絞りにより再び２つの照明光に分けて、レチクル１０を照明するように構成したものである。図４において図１に対応する部分には同一符号を付し、その詳細説明を省略する。

【００２９】図４は、本変形例の投影露光装置の概略構成を示し、この図４において、図１の光源部１と同様にフォトレジストに対して感光性の照明光ＩＬ１Ａを射出する光源部１Ａと、図１の光源部２と同様にフォトレジストに対して非感光性の照明光ＩＬ２Ａを射出する光源部２Ａとを互いに位置を代える形で配置している。そして、それらの照明光ＩＬ１Ａと照明光ＩＬ２Ａとが交差する位置に偏光ビームスプリッター３１を配置している。本変形例の照明光ＩＬ１Ａ及びＩＬ２Ａはそれぞれ Ｐ偏光の直線偏光であるとする。光源部２Ａの視野絞りから射出された波長λ２のＰ偏光の照明光ＩＬ２Ａは、リレーレンズ４Ａにより平行光束にされて偏光ビームスプリッター３１を透過し、１／４波長板３４により円偏光に変換される。一方、光源部１Ａの視野絞りから射出され、リレーレンズ３Ａにより平行光束にされたＰ偏光の照明光ＩＬ１Ａは、照明光ＩＬ２Ａの光路に直交する方向から偏光ビームスプリッター３１を透過して、１／４波長板３２を経てミラー３３により反射されて再び１／４波長板３２に入射してＳ偏光に変換される。Ｓ偏光に変換された照明光ＩＬ１Ａは、偏光ビームスプリッター３１により反射されて、１／４波長板３４に入射し、円偏光に変換される。１／４波長板３４により円偏光に変換された照明光ＩＬ１Ａ，ＩＬ２Ａは、リレーレンズ３５及び３６を経て波長選択性を有する開口絞り３７に入射する。

【００３０】図５（ａ）は、開口絞り３７の平面図を示し、この図５（ａ）において、開口絞り３７は波長λ１の照明光ＩＬ１Ａを透過し、波長λ２の照明光ＩＬ２Ａを殆ど透過しない輪帯状の光学フィルター３９と、波長λ２の照明光ＩＬ２Ａを透過し、波長λ１の照明光ＩＬ１を殆ど透過しない円形の光学フィルター３８とから構成されている。また、開口絞り３７は中心が光軸ＡＸに合致するように投影光学系１２の瞳面ＰＳと共役な面上に配置されている。そして、光源部１Ａからの照明光ＩＬ１Ａは輪帯状の光学フィルター３９を含む領域に照射され、光源部２Ａからの照明光ＩＬ２Ａは円形の光学フィルター３８を含む領域に照射されている。

【００３１】偏光ビームスプリッター３１により合成された２つの照明光ＩＬ１Ａ，ＩＬ２Ａは、開口絞り３７を通過した後、コンデンサレンズ９を介してレチクル１０上に照射される。レチクル１０のパターン像は投影光学系１２を介してウエハ１３上に投影される。投影光学系１２の瞳面ＰＳ上では、第１の例と同様の照明光ＩＬ１Ａ，ＩＬ２Ａがほぼ円形の領域を通過する。以下の照明光ＩＬ１Ａ，ＩＬ２Ａの光路は第１の例と同様につき説明を省略する。

【００３２】本変形例によれば、第１の例と同様の高次の球面収差低減効果が得られると共に、波長選択性を有する開口絞り３７により照明光ＩＬ１Ａ，ＩＬ２Ａの通過領域を規定するため、第１の例のように変形ミラー５を用いるという複雑な構成が不要である。また、波長λ２の光源部２Ａが１つで済むため、装置全体をコンパクトに構成できる。また、偏光ビームスプリッター３１で合成された直線偏光の２光束は、１／４波長板３４によって円偏光に変換されるので、ウエハ１３上に結像する

際に、レチクル１０のパターンの方向が変わっても良好な転写が行われる。なお、偏光ビームスプリッター３１に代えて図４の２点鎖線で示すように、ダイクロイックミラー３１Ａを使用することもできる。このダイクロイックミラー３１Ａは、照明光ＩＬ２Ａを透過して、照明光ＩＬ１Ａを反射する波長選択性を有し、これによって両照明光ＩＬ１Ａ，ＩＬ２Ａが無駄なく合成される。この際には１／４波長板３２，３４及びミラー３３は不要となり、構成が簡単となる。また、図４の開口絞り３７は、図１の退避交換装置８と同様の装置によって変形照明用の開口絞り３７Ａと交換できるように構成されている。

【００３３】図５（ｂ）は、変形照明を行う際に図４の開口絞り３７の代わりに用いられる波長選択性を有する開口絞り３７Ａの平面図を示し、この図５（ｂ）において、開口絞り３７Ａは、波長λ１の照明光ＩＬ１Ａを透過し、波長λ２の照明光ＩＬ２Ａを殆ど透過しない４個の小さい円形の光学フィルター４０Ａ～４０Ｄ、及びこれらの光学フィルター４０Ａ～４０Ｄを除く領域で波長λ２の照明光ＩＬ２Ａを透過し、波長λ１の照明光ＩＬ１Ａを殆ど透過しない外形が円形の光学フィルター４１から構成されている。光学フィルター４１は、図５（ａ）の光学フィルター３９の外径とほぼ等しい外径をもち、その外周近くに等角度間隔で形成された４個の小さな円形の開口部を有し、それら４個の開口部にそれぞれ光学フィルター４０Ａ～４０Ｄが設けられている。露光用の照明光ＩＬ１Ａは、４個の光学フィルター４０Ａ～４０Ｄを通過し、フォトレジストに非感光性の照明光ＩＬ２Ａは、その光学フィルター４０Ａ～４０Ｄの周囲の光学フィルター４１を通過する。これによって変形照明が行われると共に、高次の球面収差変動が抑制される。

【００３４】なお、図５（ａ）及び図５（ｂ）において、光源部１Ａからの照明光ＩＬ１Ａが透過する光学フィルター３８及び４０Ａ～４０Ｄとしては、できるだけ光源部２Ａからの照明光ＩＬ２Ａを透過しないものが、高次の球面収差変動を低減する効果が大きく、望ましい。次に、本発明の投影露光装置の実施の形態の第２の例について図６を参照して説明する。本例は、輪帯状の瞳フィルターを使用する場合に本発明を適用したものである。なお、図６において図１に対応する部分には同一符号を付し、その詳細説明を省略する。

【００３５】図６は、本例の投影露光装置の概略構成を示し、この図６において、簡単のため、投影光学系１２を上部レンズ系１２Ａ及び下部レンズ系１２Ｂに分けて説明する。本例では、それらの上部レンズ系１２Ａ及び下部レンズ系１２Ｂの間の瞳面ＰＳの近傍に図１の変形ミラー５と同様の４角錐型の変形ミラー５Ｂを配置している。図１の光源部１と同様の光源部１Ｂの視野絞りから射出されたフォトレジストに感光性の波長λ１の照明光ＩＬ１Ｂは、コンデンサレンズ４２を介してレチクル１０上に照射される。光源部１Ｂ内の開口絞りは図２（ａ）の開口絞り２６Ｃと同様の大きな円形である。レチクル１０を透過した照明光ＩＬ１Ｂは、上部レンズ系１２Ａにより光学的にフーリエ変換されて、変形ミラー５Ｂの周囲を通過する。この変形ミラー５Ｂにより、フォトレジストに感光性の照明光ＩＬ１Ｂが光軸ＡＸを中心とする円形領域で遮光される。即ち、変形ミラー５Ｂは輪帯状の瞳フィルターを兼用している。一方、図１の光源部２と同様の光源部２Ｂから射出された波長λ２のフォトレジストに非感光性の照明光ＩＬ２Ｂは、リレーレンズ４Ｂで平行光束にされた後、一部が変形ミラー５Ｂの第１の反射面でウエハ１３側に向けて反射される。この場合、図１の第１の例と同様に変形ミラー５Ｂの下方を通過した照明光ＩＬ２Ｂを反射して、変形ミラー５Ｂの第２の反射面に入射させるためのミラー７Ａ，８Ａが配置されている。

【００３６】更に、本例でも図６の紙面に垂直な方向に、変形ミラー５Ｂの第３及び第４の反射面に対して波長λ２の照明光を供給する光源部等が設けられている。変形ミラー５Ｂで反射された照明光ＩＬ２Ｂは、下部レンズ系１２Ｂを介してウエハ１３上に照射される。本例では、投影光学系１２の瞳面ＰＳに配置された変形ミラー５Ｂにより露光用の照明光ＩＬ１Ｂの光軸ＡＸ近傍の領域が遮光されるため、所定のパターンに対して輪帯状の中心遮光型の瞳フィルターを設置した場合と同様の高い解像度が得られる。また、下部レンズ系１２Ｂの硝材は、２波長の照明光ＩＬ１Ｂ，ＩＬ２Ｂにより均一な照度分布で照明されるため、高次の熱変形や屈折率の変化が抑えられ、投影光学系１２の高次の球面収差変動が抑えられる。

【００３７】なお、本発明の実施の形態の第１の例において補足したように、変形ミラー５Ｂの反射面でフォトレジストに感光性の照明光ＩＬ１Ｂを反射し、それ以外の部分でフォトレジストに非感光性の照明光ＩＬ２Ｂを透過させるような構成にしてもよい。このような構成にする場合は、図６において、光源部１Ｂ，２Ｂ、レチクル１０、上部レンズ系１２Ａ、及び関連する光学系の配置を入れ換えると共に、変形ミラーとして、中央部に照明光ＩＬ２Ｂが透過するように円形の開口を設け、その開口部の周辺に照明光ＩＬ２Ｂに対して直交する方向から入射する照明光ＩＬ１Ｂに対して輪帯状の反射面を有する変形ミラーを使用すればよい。

【００３８】次に、本発明の実施の形態の第２の例の変形例について、図７を参照して説明する。本変形例の投影露光装置の投影光学系までの構成は、図４の第１の例の変形例とほぼ同様であり（但し、開口絞り３７が省かれている）、図７において図４及び図６に対応する部分には同一符号を付し、その詳細説明を省略する。図７は、本例の投影露光装置の概略構成を示し、この図７に

おいて、投影光学系１２の上部レンズ系１２Ａ及び下部レンズ系１２Ｂの間の瞳面ＰＳの近傍に図５（ａ）の開口絞り３７と同様の波長選択性を有する開口絞り４３を配置している。光源部２Ａから射出されたフォトレジストに非感光性の波長λ２の照明光ＩＬ２Ａ、及び光源部１Ａから射出されたフォトレジストに感光性の波長λ１の照明光ＩＬ１Ａは、偏光ビームスプリッター３１で合成され、レチクル１０を透過して投影光学系１２の上部レンズ系１２Ａで光学的にフーリエ変換されて、開口絞り４３に入射する。開口絞り４３には、図５（ａ）と同様にフォトレジストに感光性の照明光ＩＬ１Ａのみを透過する輪帯状の光学フィルターと、その内側でフォトレジストに非感光性の照明光ＩＬ２Ａのみを透過する円形の光学フィルターとが形成されており、開口絞り４３は照明光ＩＬ１Ａに対して中心遮光型の瞳フィルターとして作用する。もう一方の照明光ＩＬ２Ａは照明光ＩＬ１Ａが遮光された円形領域を通過した後、下部レンズ系１２Ｂを介してウエハ１３上に入射する。

【００３９】本変形例では、投影光学系１２の瞳面ＰＳに配置された開口絞り４３により、図６の例と同様に高い解像度が得られる。また、下部レンズ系１２Ｂの硝材は、２つの照明光ＩＬ１Ａ，ＩＬ２Ａにより均一な照度分布で照明されるため、高次の球面収差変動が抑えられる。なお、光源部１Ａからの照明光ＩＬ１Ａを透過する光学フィルターとしては、光源部２Ａからの照明光ＩＬ２Ａをできるだけ透過しない光学フィルターが、高次の収差を低減する効果が大きく望ましい。なお、図４の例と同様に、偏光ビームスプリッター３１に代えてダイクロイックミラーを使用してもよい。

【００４０】次に、上述の実施の形態において、投影光学系１２のレンズに対する照度分布が均一化され、高次の収差変動が抑えられることを計算例に基づいて説明する。先ず、照明光の照射による上昇後の温度分布を計算する。レンズを円筒形に近似して、レンズの側面から周辺の空気を通して熱が流出せず、レンズの縁が金属と接することにより、その縁からのみ熱が流出し、レンズにおける吸収エネルギー密度分布が光軸ＡＸの回りの角度に対して一定であるとする。そのレンズの半径方向の距離を表す変数ｒとすれば、上昇後の温度分布は変数ｒの関数Ｔ（ｒ）となり、レンズの単位体積当たりの熱吸収量及び熱伝導率をそれぞれ、ω（ｒ）及びλとし、レンズの外半径をａとすると、熱平衡状態での円筒座標系での熱伝導方程式は、次式のように表せる。

【００４１】

【数１】$\partial^2 T/\partial r^2 + (1/r)\,\partial T/\partial r + \omega(r)/\lambda = 0$

この熱伝導方程式を解くと、次式のようになる。

【００４２】

【数２】

$$T(r) = \sum_{i=1}^{\infty} B_i J_0(p_i \cdot r)$$

【００４３】ここで、$J_n(p_i \cdot r)$ は第１種第ｎ次（ｎ＝０，１，２，…）のベッセル（Bessel）関数で、p_i は $J_1(p_i \cdot a)=0$ を満たす数列である（ｉ＝１，２，３，…）。また、係数 B_i は次式により求められる。

【００４４】

【数３】

$$B_i = 2\int_0^a \omega(r)\, J_0(p_i \cdot r)\, r\,dr \Big/ \{\lambda p_i^2 a^2 [J_1(p_i \cdot a)]^2\}$$

【００４５】特に、熱吸収量ω（ｒ）が照射領域の半径（照射半径）内で階段状の関数で表されるとき、即ち或るｊ（１≦ｊ≦Ｎ）において、変数ｒが、$h_j \leq r \leq h_{j+1}$ を満たす区間において、熱吸収量ω（ｒ）が一定値 ω_j をとるとき、次の関係が成立する。

【００４６】

【数４】

$$\int_0^a \omega(r)\, J_0(p_i \cdot r)\, r\,dr = \sum_{j=1}^{N} \int_0^a \omega_j \cdot J_0(p_i \cdot r)\, r\,dr$$

$$= \sum_{j=1}^{N} \omega_j \{h_{j+1} \cdot J_1(p_i \cdot h_{j+1}) - h_j \cdot J_1(p_i \cdot h_j)\} / p_i$$

【００４７】従って、（数４）を（数３）に代入することにより係数 B_i が求められ、この係数 B_i を（数２）に代入することにより、上昇後の温度分布Ｔ（ｒ）が求められる。次に、上昇後の温度分布Ｔ（ｒ）により、どの次数の収差変動が多く現れるかを調べるために、上昇後の温度分布Ｔ（ｒ）を以下のように最小２乗法で r^{10} の項までベキ級数展開すると、次式のようになる。

【００４８】

【数5】$T(r)=T_0+C_2\cdot r^2+C_4\cdot r^4+C_6\cdot r^6+C_8\cdot r^8+C_{10}\cdot r^{10}$

この場合、上昇後の温度分布Ｔ（ｒ）の単位は℃、変数ｒの単位はｍｍである。また、T_0 は、光軸ＡＸ、即ち変数ｒが０の位置における上昇後の温度分布Ｔ（０）である。

【００４９】以下、実際の数値に基づく計算例について説明する。投影光学系の入射側の開口数（ＮＡ）に対する照明光学系の出射側の開口数の比の値（コヒーレンスファクタ）をσ値とし、このσ値を０．７５に設定する。そして、σ値が０．７５の照明系によって外半径４０ｍｍの円筒形の石英からなるレンズが照明され、レンズ上の照射領域の半径ｄが３０ｍｍであるような場合について、（数２）～（数４）の熱伝導方程式の解に基づいて計算する。石英の熱伝導率を０．０１３８Ｗ／（ｃｍ・℃）とし、ウエハ上のフォトレジストに感光性の照明光に対するレンズの熱吸収率を２％／ｃｍとする。

【００５０】第１の計算例では、先ず比較のため、照明光の全照射エネルギー量が１Ｗで、σ値が０．７５の範囲内でレンズが一様に照射されている場合について計算する。図８（ａ）は、第１の計算例による上昇後の温度分布Ｔ（ｒ）を示し、横軸は変数ｒ、縦軸は上昇後の温度分布Ｔ（ｒ）を表す。実線の曲線４６Ａに示すように、上昇後の温度分布Ｔ（ｒ）は原点、即ち光軸ＡＸに最大値を有し、光軸ＡＸに関して軸対称な山型の変化を示す。なお、参考として、照明光の照射エネルギー密度Ｐ（ｒ）を点線４７Ａにより示す。照射エネルギー密度Ｐ（ｒ）は、変数ｒが０～ｄ（照射半径）の間で一定の値Ｐ１となる。また、光軸ＡＸでの温度分布T_0、及び温度分布Ｔ（ｒ）を（数５）によりベキ級数に展開したときの係数C_2～C_{10}を表１に示す。

【００５１】

【表１】

光軸における上昇後の温度分布T_0	１．８１８２×１０$^{-1}$
係数	
C_2	－１．３４５０×１０$^{-4}$
C_4	４．４０００×１０$^{-8}$
C_6	－９．９００６×１０$^{-11}$
C_8	８．２９８３×１０$^{-14}$
C_{10}	－２．０７４５×１０$^{-17}$

【００５２】次に、第２の計算例について説明する。この計算例は輪帯照明だけ行われた場合の例であり、第１の計算例と同様に比較のための計算例である。σ値は最大で０．７５で、輪帯の内側のσ値は０．５である。そのσ値が０．５～０．７５の間でレンズが一様に照明され、全照射エネルギー量が１Ｗである場合について上昇後の温度分布Ｔ（ｒ）を計算したものである。

【００５３】図４（ｂ）は、第２の計算例による上昇後の温度分布Ｔ（ｒ）を示し、この図４（ｂ）において、実線の曲線４６Ｂに示すように、上昇後の温度分布Ｔ（ｒ）は変数ｒがほぼ０～ｅの間で一定の上昇温度ＴＢとなる。点線４７Ｂで示す照射エネルギー密度Ｐ（ｒ）は、変数ｒがｅ～ｄの間で一定の値Ｐ２となり、変数ｒが０～ｅの間では０となっている。第１の計算例と同様に、光軸ＡＸでの上昇後の温度分布T_0、及び上昇後の温度分布Ｔ（ｒ）を（数５）によりベキ級数に展開したときの係数C_2～C_{10}を表２に示す。

【００５４】

【表２】

光軸における上昇後の温度分布T_0	１．０７４４×１０$^{-1}$
係数	
C_2	－３．４３２１×１０$^{-5}$
C_4	２．７３２８×１０$^{-7}$
C_6	－６．３９６１×１０$^{-10}$
C_8	４．５３１９×１０$^{-13}$
C_{10}	－１．０５１３×１０$^{-16}$

【００５５】次に、第３の計算例について説明する。この計算例は、図１、図４、図６、図７に示す実施の形態のように、ウエハ１３上のフォトレジストに感光性の照明光及びそのフォトレジストに非感光性の照明光の２つの照明光によりレンズが照明されている場合の上昇後の温度分布Ｔ（ｒ）を求めるものである。この場合、σ値が０．７５から０．５の範囲内では、フォトレジストに感光性の照明光により全照射エネルギー量が１Ｗでレンズが一様に照明され、σ値が０．５から０．０の範囲内においては、フォトレジストに非感光性の波長の照明光により、照射エネルギー密度Ｐ（ｒ）がσ値が０．７５から０．５の範囲での照射エネルギー密度の１／２になるようにレンズが照明されているものとする。

【００５６】図４（ｃ）は、第３の計算例による上昇後の温度分布Ｔ（ｒ）を示し、この図４（ｃ）において、実線の曲線４６Ｃに示すように、上昇後の温度分布Ｔ（ｒ）は原点、即ち光軸ＡＸに最大値ＴＣを有し、光軸ＡＸに関して軸対称な山型の変化を示す。また、照射エネルギー密度Ｐ（ｒ）は階段状に変化する点線４７Ｃに示すように、変数ｒがｅ～ｄの間で一定の値Ｐ２となり、変数ｒが０～ｅの間では一定の値Ｐ３（＝Ｐ２／２）となっている。また、光軸ＡＸでの温度分布T_0、及び温度分布Ｔ（ｒ）を（数５）によりベキ級数に展開したときの係数C_2～C_{10}を表３に示す。

【００５７】

【表３】

光軸における上昇後の温度分布T_0	2．1736×10^{-1}
係数 C_2	－1．3821×10^{-4}
C_4	1．7624×10^{-7}
C_6	－4．0891×10^{-10}
C_8	3．0128×10^{-13}
C_{10}	－7．1235×10^{-17}

【0058】なお、第1及び第2の計算例においては、全照射エネルギー量を1Wとし、第3の計算例においては、σ値が0．75から0．5の範囲内における照射エネルギー量を1Wとしている。この第3の計算例においては、σ値が0．5～0．0の範囲における照射エネルギー量を加えると、全照射エネルギー量は1Wを超える。これは、第1～第3の計算例におけるウエハ13上のフォトレジストに感光性の照明光の照射エネルギー量を等しくして、露光時間（スループット）が等しくなるように設定したものである。

【0059】第1の計算例に示す照明形態（一様照明）と、第2の計算例に示す照明形態（輪帯照明）とを比較した場合、表1及び表2で示すように、輪帯照明の方が一様照明に比較して、光軸ＡＸにおける上昇温度が低い。それにもかかわらず、例えばベキ級数の係数C_4を比較すると、一様照明の場合の係数C_4の値が、4．4000×10^{-8}に対して、輪帯照明の場合の係数C_4は、2．7328×10^{-7}と、輪帯照明の方が大きくなっている。即ち、一様照明と輪帯照明とを比較すると、係数C_2以外のベキ級数の係数の絶対値は全て輪帯照明の方が大きくなっている。熱変形や屈折率変化は上昇後の温度分布Ｔ（ｒ）に比例するので、収差変動も上昇後の温度分布Ｔ（ｒ）に比例する。係数C_2より高次のベキ級数の係数が全て輪帯照明の方が大きいということは、輪帯照明の方が高次の収差変動が大きいことを意味する。

【0060】ここで、図1、図4、図6、図7に示す実施の形態での照明形態を「合成照明」とすれば、合成照明により光軸近傍にも照明光を照射すると、第3の計算例に示すように、全照射量が一様照明や輪帯照明よりも多いのにもかかわらず、表1及び表2に示すように、係数C_4の値（＝1．7624×10^{-7}）は、輪帯照明での係数C_4の値（＝2．7328×10^{-7}）よりも小さくなっている。更に、係数C_6, C_8, C_{10}の絶対値を比較すると、何れの係数においても合成照明の方が輪帯照明よりも小さくなっている。これは、合成照明により高次の収差変動が小さくなることを意味する。

【0061】また、第3の計算例においては、σ値が0～0．5の間における照射エネルギー密度を、σ値が0．5～0．75の間における密度分布の1／2としたが、σ値が0～0．75の範囲において全て一様な照射エネルギー分布により照射されている場合の温度分布Ｔ（ｒ）について計算し、図4（ｂ）の輪帯照明の場合と比較してみる。

【0062】図8（ａ）のエネルギー密度Ｐ1と図8（ｂ）の照射エネルギー密度Ｐ2との間には、Ｐ2＝1．8・Ｐ1の関係が成立する。従って、図8（ｂ）のような輪帯照明において、σ値が0．5以内の範囲も輪帯照明領域と等しい照射エネルギー密度で照射する場合には、図8（ａ）において、照射エネルギー密度を1．8倍した状態と等価である。従って、ベキ級数の係数も全て1．8倍されるので、表1における係数C_4, C_6, C_8, C_{10}はそれぞれ、7．9200×10^{-8}, －1．7821×10^{-10}，1．4937×10^{-13}，－3．7341×10^{-17}となる。これらの係数の値を表2のそれぞれの係数と比較した場合、光軸ＡＸ近傍の上昇後の温度分布T_0が輪帯照明の場合よりもかなり大きいにもかかわらず、係数C_4～C_{10}までの係数は輪帯照明の場合より全て小さくなっている。即ち、合成照明によりσ値が0～0．75の範囲内において、輪帯照明と同じ照射エネルギー密度Ｐ2で照射した場合でも、輪帯照明の場合より高次の収差変動が少ないことを意味している。

【0063】なお、上述の実施の形態はステッパー型の投影露光装置に本発明を適用したものであるが、本発明はステップ・アンド・スキャン方式のような走査露光型の投影露光装置にも適用できる。なお、本発明は上述の実施の形態に限定されず、本発明の要旨を逸脱しない範囲で種々の構成を取り得ることは勿論である。

【0064】

【発明の効果】本発明の第1の投影露光装置によれば、投影光学系の瞳面と共役な面上で光軸から偏心した領域に分布する光源からの露光用の照明光を用いるため、例えば輪帯照明又は変形照明を行う場合と同じような解像力向上の効果が得られる。また、輪帯照明や変形照明を行う場合に露光用の照明光が通過しない領域に、非感光性の照明光を照射しているため、投影光学系のレンズの高次の熱変形や屈折率変化が減少し、投影光学系の高次の球面収差変動が抑えられる利点がある。

【0065】また、照明光学系が、輪帯状の光源、又は光軸に対して偏心した位置にある複数の光源からの露光用の照明光でマスクを照明する場合には、所謂輪帯照明や変形照明により高い解像度が得られる。また、照明光学系が、露光用の照明光の照度分布を均一化するためのオプティカル・インテグレータを有し、オプティカル・インテグレータとマスクとの間に、補助照明系からの照明光をマスクに導く補助光導入部材を設ける場合には、露光用の照明光と非感光性の照明光とを瞳面と共役な面上で正確に分離した状態でマスクを照明でき、結像特性が劣化しない利点がある。

【0066】また、本発明の第2の投影露光装置によれば、波長選択性を有する光学部材によって投影光学系の

瞳面上で光軸から偏心した領域を通過する結像光束を用いるため、輪帯状の中心遮光型の瞳フィルターを設置した場合と同様の解像度が得られる利点がある。更に、投影光学系の瞳面近傍のレンズは、露光用の照明光と感光基板に非感光性の照明光との２つの照明光により均一な照度分布で照射されるため、レンズの熱変形や屈折率の高次の変動成分が減少し、投影光学系の高次の球面収差変動が減少する利点がある。

【図面の簡単な説明】

【図１】本発明の投影露光装置の実施の形態の第１の例を示す概略構成図である。

【図２】図１の光源部に設けられた各種の開口絞りを示す拡大平面図である。

【図３】（ａ）は図１の変形ミラー５をレチクル側から見た図、（ｂ）は別の変形ミラー５Ａをレチクル側から見た図である。

【図４】本発明の実施の形態の第１の例の変形例を示す概略構成図である。

【図５】（ａ）は図４中の開口絞り３７を示す平面図、（ｂ）は別の開口絞り３７Ａを示す平面図である。

【図６】本発明の投影露光装置の実施の形態の第２の例を示す概略構成図である。

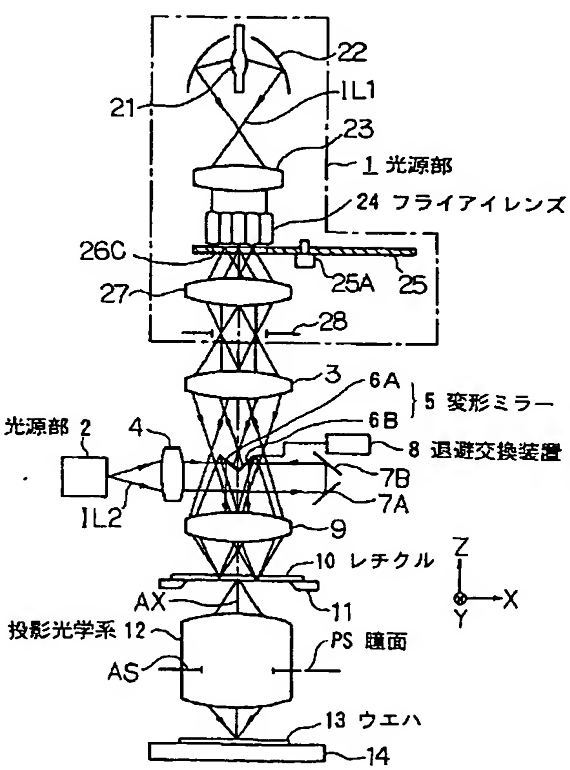
【図７】その実施の形態の第２の例の変形例を示す概略構成図である。

【図８】本発明の実施の形態において、照射エネルギーによる温度分布計算例を説明するための図である。

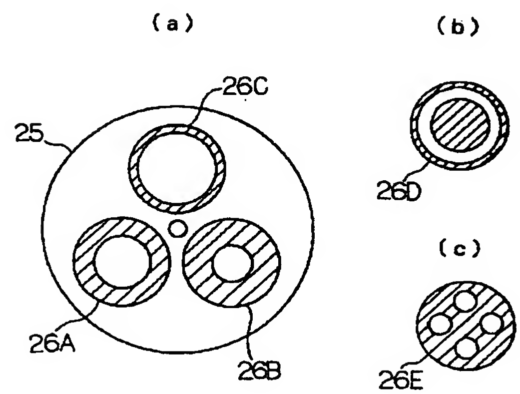
【符号の説明】

１，１Ａ，１Ｂ　光源部（露光用）
２，２Ａ，２Ｂ　光源部（非露光用）
５，５Ａ，５Ｂ　変形ミラー
６Ａ～６Ｄ，１９Ａ～１９Ｄ　ミラー
１０　レチクル
１２　投影光学系
１２Ａ　上部レンズ系
１２Ｂ　下部レンズ系
ＰＳ　瞳面
１３　ウエハ
１４　ウエハステージ
２４　フライアイレンズ
２６Ａ～２６Ｃ　開口絞り
３１　偏光ビームスプリッター
３２，３４　１／４波長板
３７，３７Ａ，４３　波長選択性を有する開口絞り

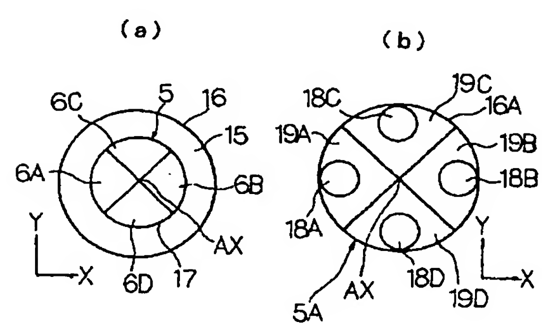
【図１】



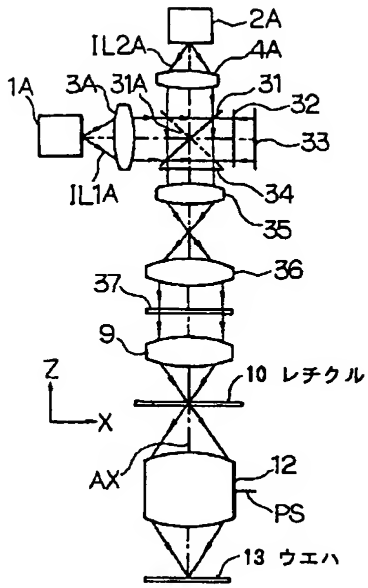
【図２】



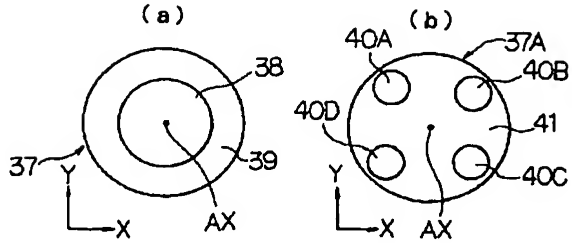
【図３】



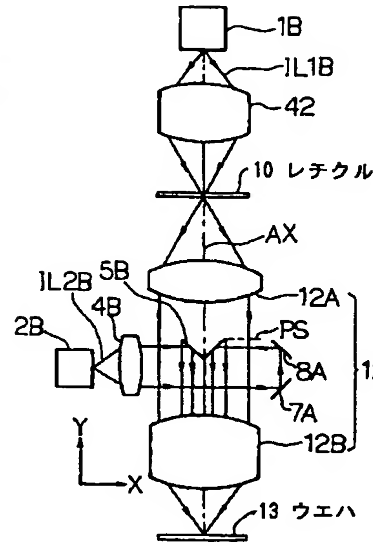
【図４】


2A
IL2A
4A
1A
3A
31A
31
32
33
IL1A
34
35
36
37
9
10 レチクル
Z
X
AX
12
PS
13 ウエハ

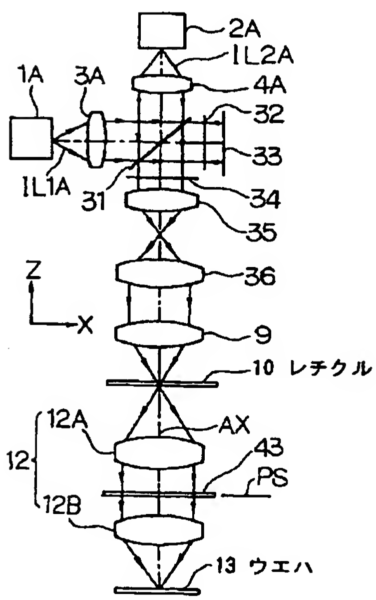
【図５】


(a)
38
37
39
Y
X
AX
(b)
40A
37A
40B
40D
41
40C
Y
X
AX

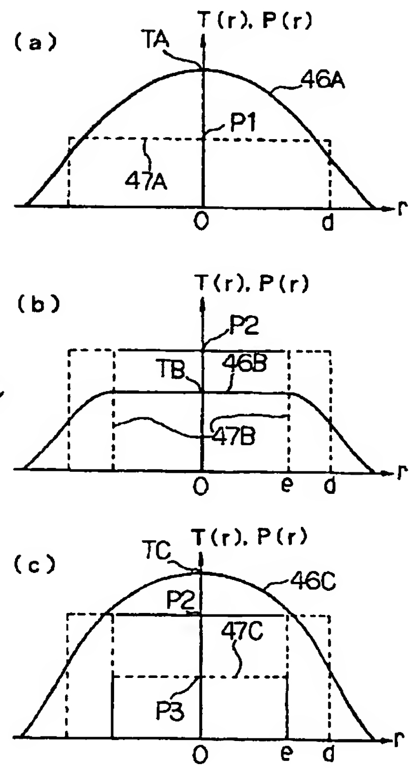
【図６】


1B
IL1B
42
10 レチクル
AX
IL2B
5B
12A
4B
PS
2B
8A
12
7A
Y
X
12B
13 ウエハ

【図７】


2A
IL2A
1A
3A
4A
32
33
IL1A
31
34
35
Z
X
36
9
10 レチクル
12A
AX
43
12
PS
12B
13 ウエハ

【図８】


(a)
T(r), P(r)
TA
46A
P1
47A
0
d
r
(b)
T(r), P(r)
P2
TB
46B
47B
0
e
d
r
(c)
T(r), P(r)
TC
46C
P2
47C
P3
0
e
d
r